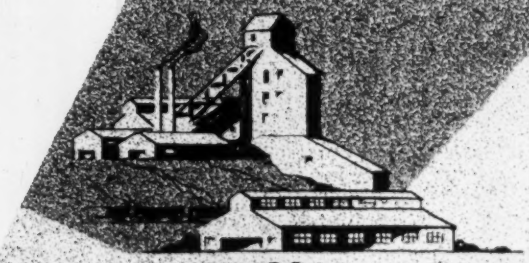
MECHANICAL ENGINEERING

July 1928



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The Monthly Journal Published by

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F. G. Straub

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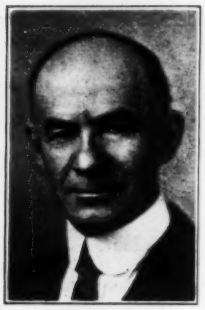


E. A. Forward

J. P. Hogan

Contributors to This Issue

William Kelly is vice-president of engineering and operation, Buffalo, Niagara and Eastern Power Corporation. During the War Colonel Kelly was successively Member General of the Munitions Board, Chief Engineer of the 42d Division, Chief Engineer 4th Army Corps, Commander of Base Sections 9 and 7, A.E.F., Deputy Chief of Staff, A.E.F., and Assistant to the American Peace Commission. Since 1920 he has been connected with the California Debris Commission, the Federal Water Power Commission and with the National Electric Light Association as director of engineering. He has also been associated with the Joint Board of Engineers on the St. Lawrence River Project.

E. A. Forward, consulting engineer, Montreal, Canada, is a Canadian by birth. He was educated at the School of Practical Science and the University of Toronto. During his professional career Mr. Forward has been connected with the construction department of the St. Lawrence Canals; the Georgian Bay canal survey; the St. Andrews lock and dam; as construction engineer with the firm of Quinlan & Robertson on the Montreal aqueduct, the St. Charles River improvements, etc. Since 1921 he has been in private consulting practice, and has also acted as chief engineer of the firm of Quinlan, Robertson & Janin, Ltd.

John P. Hogan, member since 1926 of the firm of Parsons, Klapp, Brinckerhoff & Douglas, engineers, New York City, is a graduate of Harvard University. He was connected with the New York Board of Water Supply from 1906 to 1920, the last year of which he served as acting deputy chief engineer. He was for six years associated, as consulting engineer, with William Barclay Parsons in charge of the New York Water Power Investigation. In addition to holding his present position, Mr. Hogan is also consulting engineer for a number of the power companies in the eastern and northeastern states.

S. W. Parr, President of the American Chemical Society, was graduated at the University of Illinois in 1884 and afterward studied at Cornell, Berlin, and Zurich. Quite early in his career he turned his attention to the study of coal, and his sodium peroxide calorimeter first made it practically possible to determine the value of commercial coals economically for many samples. From that he was led to the study of the chemical composition and classification of coals, until he is now an international authority on questions of this kind.

F. G. Straub received his B.S. degree in chemical engineering at the University of Illinois, in 1920. He then became a research fellow at Mellon Institute, and later entered the employ of the Semet-Solvay Co., Syracuse, N. Y., on development work on coking processes. In 1921 he became associated with Pennsylvania State College where he was a teaching fellow for one year. He received his M.S. degree from this college in 1923, and then was connected for a short time with the Guggenheim Brothers Research Laboratory until he returned to the University of Illinois in December, 1924, where he has since been engaged with the Utilities Research Commission's research work on boiler-feedwater treatment.

L. B. Bonnett

G. A. Pennock

E. G. Grace, president of the Bethlehem Steel Corporation, was graduated at Lehigh University in 1899 with the degree of E.E., and immediately entered the employ of the Bethlehem Steel Co. In 1911 he was appointed vice-president and general manager of the company, and two years later, president. He was elected president of the Bethlehem Steel Corporation in 1916.

L. B. Bonnett, purchasing agent of the Brooklyn Edison Co., Inc., was graduated from Syracuse University in 1910 with the degree of E.E. He immediately entered the employ of the General Electric Co. at Schenectady in their test department, and was engaged in engineering work until 1919 and in sales work until 1923. In that year he entered the employ of the Brooklyn Edison Co. as inside plant engineer responsible for the electrical design of generating and substations.

G. A. Pennock is superintendent of inspection of the Hawthorne Works of the Western Electric Co., Inc., at Chicago. He holds the degree of B.S. from the Massachusetts Institute of Technology. From 1900 to 1901 he was Secretary of the Kansas City Bolt & Nut Co. and from 1901 to 1903 was chief draftsman of the Webber Gas & Gasoline Engine Co. of Kansas City. In 1903 he became mechanical superintendent of the Rock Island Plow Co., which position he held until 1906, when he joined the Western Electric Co. as factory engineer.

This Month's Cover is a photograph of the Cedars Plant of the Montreal Light, Heat and Power Consolidated, used in connection with the leading article on the St. Lawrence Waterway.

MECHANICAL ENGINEERING

Volume 50 July, 1928 No. 7

The St. Lawrence Waterway

A Symposium[1] Dealing With the Waterway Itself and With Its Power and Navigation Potentialities

In the first of this group of three papers, particulars are given of the waterway itself and its five sections, of the improvements recommended by the Joint Board of Engineers of the United States and Canada, and of ice conditions which will have to be overcome in order that the full power capacity of the river may be utilized. The second paper deals with transportation problems, character of the traffic, possible savings in cost of freight carriage, and improvements necessary to combined navigation and power development. In the third paper estimates are made of the cost of generating power at the most favorable site, and questions involved in the problem of marketing the power are discussed.

The St. Lawrence Waterway

By WM. KELLY,[2] BUFFALO, N. Y.

THE St. Lawrence River runs from the Great Lakes to the ocean. From the point where it leaves Lake Ontario it lies along the boundary between the United States and Canada for a distance of 115 miles. It then flows through the Province of Quebec to the Gulf of St. Lawrence. Montreal lies 180 miles downstream from Lake Ontario.

There is now a channel 30 ft. deep from Montreal to the ocean, and a project is under way to enlarge this channel to a depth of 35 ft.

The interconnecting channels from Lake Superior to Lake Erie have been improved by channel excavation and by locks at St. Mary's Falls to provide a route available for vessels of 20 ft. draft. A report on the advisability and cost of further improvement of interlake channels has been directed by Congress and is now in preparation.

The Welland Canal, built and operated by Canada, connects Lake Erie with Lake Ontario. The canal will accommodate vessels of 14 ft. draft and 260 ft. length. It is 27 miles long and has 25 locks to overcome the difference of level of 326 ft. Canada is now constructing a new Welland Ship Canal, which is expected to be completed in 1930. The new canal has seven locks 766 ft. long, 30 ft. deep, and 80 ft. wide. It has an initial depth of 25 ft. in earth and 27 ft. in rock, and is designed to permit deepening to 30 ft. when necessary.

The St. Lawrence

The St. Lawrence from Lake Ontario to Montreal can be divided into five sections, as follows:

1 The Thousand Islands Section, from Lake Ontario to Galop Rapids, is 67 miles long and has a fall of 1 ft.

2 The International Rapids Section, from Galop Rapids to Cornwall, is 49 miles long and has a fall of 92 ft. In this section are found the Galop, Rapide Plat, and Long Sault Rapids.

3 The Lake St. Francis Section, from Cornwall to Coteau, is 26 miles long and has a fall of 1 ft.

4 The Soulanges Section, from Lake St. Francis to Lake St. Louis, is 18 miles long and has a fall of 83 ft. In this section are the Coteau, Cedars, and Cascades Rapids.

5 The Lachine Section, from Cascades Rapids to Montreal Harbor, is 23 miles long and has a fall of 48 ft. In this section are Lake St. Louis, Lachine Rapids, and La Prairie Basin.

The St. Lawrence is a clear-water stream with a remarkably uniform flow. The flow varies from about 190,000 to 320,000 cu. ft. per sec. The banks are low, and the absence of floods has tempted the property owners along the river to build their improvements down to the water level. Both of these conditions add to the difficulty and expense of improving the river for navigation and power.

The St. Lawrence is a large river, and damming it is a major operation. Consequently navigation improvements to date have consisted of side canals, with locks, around the rapids.

The first canals were built about 1770. Each time new facilities were needed, new canals were built and the old ones abandoned. At some of the rapids the remains of three canals are found. The present canal system has been in use about 30 years and consists of a series of canals around the rapids. The total length of canals is 46 miles, and there are 28 locks. The locks are the same size as those on the old Welland Canal.

Commerce on the St. Lawrence has been growing rapidly since the war. In 1926 it amounted to about 6,000,000 tons, and last year it ran to over 7,000,000 tons. The estimated capacity of the canals is about 8,000,000 tons per year. Even if prospective ocean traffic on the river be disregarded, improved facilities are now needed to care for the traffic already developed on the St. Lawrence.

Present Power Developments

At Massena the Aluminum Company of America has a power plant of about 80,000 hp. In the Soulanges Section there are four power plants with a combined capacity of about 240,000 hp. The largest of these is the Cedars Plant, owned and operated by the Montreal Light, Heat, and Power Company. In the Lachine Section there is an old plant which has not been operated for some years.

Studies for Improvement

Shortly after the World War the two countries arranged to consider the further improvement of the St. Lawrence from

[1] Three papers, by Messrs. Wm. Kelly, E. A. Forward, and John P. Hogan, presented at a joint meeting of the Metropolitan Section of the A.S.M.E. and the New York Sections of the A.S.C.E. and the A.I.E.E., New York, March 6, 1928.

[2] Vice-President, Buffalo, Niagara & Eastern Power Corporation.

Lake Ontario to Montreal. The question was referred to the International Joint Commission, a permanent body created by treaty to deal with matters relating to boundary waters. Plans for the improvement were prepared in 1921 by a board composed of one engineer for the United States and one for Canada. The Joint Commission recommended that the two countries enter into a treaty arranging for the improvement, but, as it had received certain alternative plans for the improvement of the International Section, it further recommended that all plans presented be reviewed by an enlarged engineering board. In 1924 the two governments appointed such a board, known as the Joint Board of Engineers on the St. Lawrence Waterway.

The Joint Board consisted of six engineers, three from each country, and submitted its report in November, 1926.

Fairchild Co., Grand Mere, Canada

AIRPLANE VIEW OF WELLAND CANAL, WATERWAY CONNECTING LAKE ERIE AND LAKE ONTARIO

IMPROVEMENT RECOMMENDED

The improvement of the Thousand Islands Section requires simply the removal of certain rock reefs in the river and the cutting back of a few projecting points in the narrow reaches between islands so as to afford safe and convenient navigation. The improvement of the Lake St. Francis Section requires only the dredging of deep channels through shoals in the lake. Neither of these two sections offers any engineering difficulties. The real engineering problems of the project lie in the improvement of the three rapids sections.

There are two practicable methods of carrying navigation past the rapids. One is that heretofore used, namely, the construction of lateral canals with locks, and the other is the drowning out of the rapids with dams having locks to carry navigation past the dams. The existing canals carry an important traffic and must be kept in operation until a new waterway is opened. Their enlargement is therefore impracticable, and even if practicable would be undesirable on account of the delays to shipping incident to the large number of locks involved.

New lateral canals can be built at less expense than dams, but afford slower and more restricted navigation. Moreover the concentrated fall at the dams affords the means of developing the large potential power in the river, the value of which is an offset to the cost of pool navigation.

The advantage of combining power with navigation improvement is particularly great in the International Rapids Section.

The extent to which the development of power can be advantageously combined with navigation improvement depends largely upon the rate at which power can be marketed. The plans presented by the Joint Board of Engineers provide for an initial power development in conjunction with navigation improvement which is based on conservative estimates of the rate at which power can be marketed under Canadian restrictions as to export. They also provide for the ultimate utilization of the complete power resources of the river.

The level of the water surface in Montreal Harbor is 18 ft. or more above sea level, and the depths in the harbor and in the sloping channel from Montreal to Quebec are dependent upon the flow in the river. It is essential, therefore, that the dams and power houses shall be designed and operated in such a manner as not to cause fluctuations in the flow of the river. This limitation makes the power development a run-of-stream proposition.

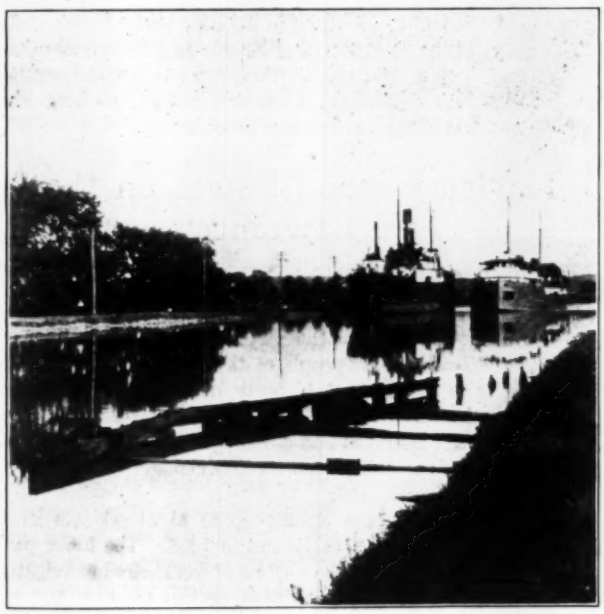
ICE CONDITIONS

Winter operation of power plants on the St. Lawrence involves difficulties. If the output of power plants is to be maintained in the winter, means must be found to insure the discharge capacity of the river without excessive loss of head from ice gorging.

The rapids of the river now run open during the winter. From the time the water reaches the freezing point in late December or early January until the end of the winter, these exposed reaches

are steadily making ice in the form of frazil and anchor ice. The frazil collects in masses of snowlike ice which float down the surface. The anchor ice breaks loose under changing weather conditions and joins the frazil on the surface. At the foot of the rapid sections where the velocity is low, an ice sheet forms early in the winter. The floating slush ice packs against this sheet and extends it upstream until the ice cover reaches a point where the velocity is great enough to carry the slush under the ice cover, when a hanging dam is formed, which gorges the river. The gorging causes a rise in the water surface which reduces the velocity and permits the ice pack to extend further upstream. By the end of the winter the accumulations of ice at the foot of the rapids extend for miles and cause the water level to rise from 10 to 30 ft. A dam in any of the rapid reaches of the river will form a deep pool certain to freeze over early in the winter, but the upper portions of the rapids must remain open because the water levels at the head of the three rapid reaches cannot be raised without producing excessive flood damage. Raising the water level at the head of the International Rapids Section would flood the cities on Lake Ontario; at the head of the Soulanges Section it would flood large areas of land around Lake St. Francis, and at the head of the Lachine Section it would flood the suburban developments around Lake St. Louis.

For successful winter operation it is necessary to prevent ice gorging at the head of the ice-covered pool formed by the dam. The plans of the Joint Board provide for enlarging the upper reaches of the rapids by excavation to produce current velocities so low as to permit an ice pack to form without gorging except



Ewing Galloway, N. Y.

AMERICAN FREIGHTERS IN WELLAND CANAL AT THOROLD, ONTARIO, CANADA

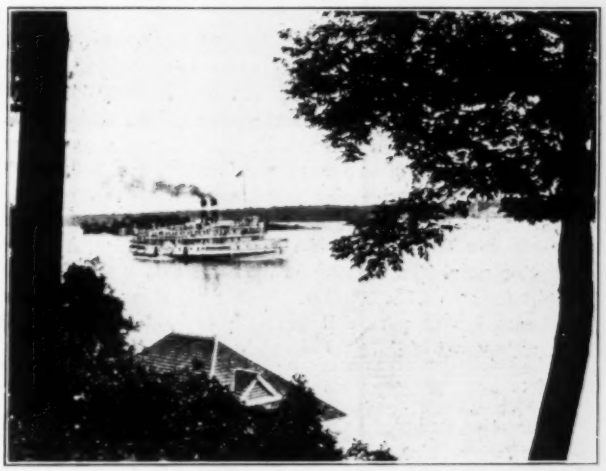
through short distances at the extreme upper end of the reach where the remaining area of open water will not produce enough ice to cause trouble. Since there is no marked spring rise on the upper St. Lawrence, the spring break-up of the ice sheet will occur quietly and without the jams found on rivers subject to spring floods.

The excavation involved in this method of improvement is very great, but the studies of the Board show conclusively that in no other way can the full power capacity of the river be conserved.

THE INTERNATIONAL RAPIDS SECTION

In this section the canalization of the river by dam or dams for the joint benefit of navigation and power undoubtedly gives the best method of improvement. The length of the section, 49 miles, is such that a side canal for navigation would be very costly and would impose serious restrictions on navigation.

Two plans for improvement were prepared by the Joint Board. One of these plans proposed to convert the entire section



Ewing Galloway, N. Y.

VIEW OF THE ST. LAWRENCE RIVER, THOUSAND ISLANDS SECTION

into a single pool with a dam about 85 ft. high at the foot of the reach at Barnhart Island. This has been called the single-stage development.

The second plan is a two-stage development. The upper pool or stage will be formed by a dam and power houses at Ogden Island, and the lower pool by a dam and power houses at Barnhart Island. The lower pool would have a height about 18 ft. less than in the single-stage plan. The two-stage development will have one more lock, will produce about 110,000 hp. less, and will cost about $30,000,000 more than the single-stage development. The advantages claimed for the two-stage plan are that power from the upper stage can be developed and marketed somewhat sooner than with the single-stage development, and about 10,000 acres less land will be flooded.

An alternative two-stage development places the upper dam at Crysler Island, about 7 miles downstream from Ogden Island, and gives about seven feet more head at the upper power houses. The alternative plan will cost about $5,000,000 more than the other two-stage plan, but will give considerably better operating conditions at the upper power houses on account of the greater head.

The cost of the single-stage development complete with an installed capacity of 2,326,000 hp. is $235,000,000. The works required for navigation will cost $25,000,000, the remainder, $210,000,000, being required for the power development, whether or not navigation is provided. It seems fair to assume, therefore, that the arrangements made for financing the power development may determine the choice of the plan ultimately chosen.

THE SOULANGES SECTION

In the Soulanges Section extending 18 miles from Lake St. Francis to Lake St. Louis there is a fall of 83 ft.

Studies of the prospective market for power in Canada indicate that complete development of power in this section in conjunction with the initial navigation improvement would not be justified. The Joint Board found, however, that it is prac-

ticable to combine development for navigation with a partial development of power on a plan that will permit the progressive development of the remaining power as needed.

The plan provides for the construction of a dam and power houses at the head of Cedars Rapids, which would create a navigable pool in the upper part of the section and afford a head of 22 ft. Navigation would enter this pool from Lake St. Francis through a canal three miles long with one low-lift lock, and would pass from the pool to Lake St. Louis through a canal five miles long with two locks.

The cost of this initial development with 382,000 hp. installed is $104,000,000. The remainder of the power, about 720,000 hp., can be developed in two steps at a cost of about $100,000,000.

A plan for the immediate development of the entire power resources and utilization of the entire river course for navigation by the construction of two dams was found to cost $10,000,000 less than the progressive plan recommended. It was regarded as meriting serious consideration if a market for the large amount of power can be found within a reasonable time. A lateral navigation canal 15 miles long on the south side of the river can be built for about $34,000,000. Such a canal entails the least initial cost, but no part of it can be incorporated subsequently in a development of the river channels for freer navigation.

The Lachine Section

This section includes Lake St. Louis and ten miles of rapids and shoals from that lake to Montreal Harbor. The total fall through the section is 48 ft., but the winter rise in Montreal Harbor due to ice gorging reduces the winter head to about 30 ft.

The Joint Board found that it was not feasible to use any part of the river channel below Lake St. Louis for navigation on account of the great cost for rock excavation. The plan recommended provides a side canal with three locks along the bank of the river, where it will not interfere with the future growth of Montreal nor with land traffic.

In order to reduce excavation in the upper part of the navigation canal and in the channel through the long shoal at the foot of Lake St. Louis, the plans include the construction of a control dam in the river below the lake by which the levels of the lake can be held up during the navigation season. The dam is to be of the rolling-shutter type, and can be entirely opened in winter so that the winter regimen of the river will not be changed. The entire cost of improvements in this section is $53,000,000. The plans are arranged so as to permit of the ultimate development of the power resources of this section.

General

All permanent structures in the Joint Board plans are designed for a depth of 30 ft. Lock dimensions are the same as for the new Welland Ship Canal, 766 ft. long and 80 ft. wide in the clear. All locks are designed so that they can be duplicated whenever traffic may require.

The costs that have been given are for initial channel depths of 25 ft. To provide initial channel depths of 27 ft. would cost $5,800,000 more for the St. Lawrence improvement. The extra depth, however, would be of little use without a corresponding deepening of lake channels which would cost about $22,000,000 more. Deepening lake harbors to 27 ft. would add considerably more.

If a 25-ft. depth be provided initially, a later deepening to 30-ft. depth will cost about $80,000.000 for the entire lake system, $25,000,000 of which would be required for the St. Lawrence itself.

An initial depth of 25 ft. would permit use of the St. Lawrence by the largest lake steamers and would accommodate 75 per cent of the ocean vessels entering and clearing at our ocean ports in October, 1924 (excluding the large passenger boats and tankers).

The plans of the Joint Board provide a navigation route from Lake Ontario to Montreal with a total, depending upon the plan adopted, of from 16 to 25 miles of canal navigation, 8 to 9 locks, and 8 bridges. The capacity on 25 ft. depth is estimated at 24,000,000 tons per annum. The cost of initial works, including the installation of 2,730,000 hp., will be $394,000,000 if the single-stage plan be used in the International Rapids Section, and $428,000,000 with 2,619,000 hp. if the double-stage plan be adopted.

A commission headed by Mr. Herbert Hoover was appointed by the President of the United States to advise on the development of a shipway from the Great Lakes to the sea. The conclusions reached by this commission are:

1 The construction of a shipway from the Great Lakes to the sea is imperative both for the relief and for the future development of a vast area in the interior of the continent.

2 The shipway should be constructed on the St. Lawrence route provided suitable agreement can be made for its joint undertaking with the Dominion of Canada.

3 The development of the power resources of the St. Lawrence should be undertaken by appropriate agencies.

4 Negotiations should be entered into with Canada in an endeavor to arrive at agreement upon all these subjects. In such negotiations the United States should recognize the proper relations of New York State to the power development in the International Section.

It appears from recent newspaper statements that negotiations with Canada may be begun in the near future.

The report of the Joint Board of Engineers demonstrates that from an engineering point of view there can be no question as to the practicability of the St. Lawrence route whenever the political and financial questions can be adjusted.

Navigation and Power on the St. Lawrence[3]

By E. A. Forward,[4] Montreal, Quebec

In the past few years we have heard much of the St. Lawrence River as a "new route to the Atlantic seaboard," or "a new outlet to the sea" for the people of the Middle West. To us Canadians it is the ancient highway of our forefathers, the main artery which carries the life blood of our overseas commerce, a natural heritage improved and developed by successive generations as the needs of growing population demanded, and as the national resources permitted.

Ocean vessels have been coming up to Montreal ever since Jacques Cartier landed on the island in 1535. The lower part of the river was charted by the celebrated world-circumnavigator Captain Cook for Wolfe's expedition against Quebec, and his chart is still the foundation of the present charts of the river.

Up to 1851 the draft of vessels was limited to 11 ft. at low-water periods, but during the four following decades the channel was deepened to 27½ ft. The inception of this improvement was entirely due to the merchants of Montreal, and it was carried on by the Montreal Harbor Commission until 1888, when it was taken over by the Dominion Government. Since that time the channel depth has been increased to 30 ft., and a projected 35-ft. channel is about half completed.

The aids to navigation now installed make the movement of

[3] A paper dealing with the same subject-matter was presented by Mr. Forward at the Midwest Power Conference, Chicago, February 14 to 17, 1928.

[4] Consulting Engineer. Member, Engineering Institute of Canada.

ocean vessels up and down this waterway as safe as on the high seas.

The Lachine Rapids interposed an obstacle which prevented the early navigators from ascending the river above Montreal. Efforts to overcome this barrier began in the year 1700. In the years 1779–1783 the Royal Engineers built canals to overcome the series of rapids between Lake St. Louis and Lake St. Francis.

The construction of nine-foot canals began on the Lachine about 1820, and by the year 1848 the entire system between Montreal and Lake Ontario was completed for 9 ft. draft, and open for traffic. A further enlargement to 14 ft. depth was completed in 1900 and has since been in operation. Meanwhile the Welland Canal was built and enlarged to the same depth.

Between Lake Huron and Lake Superior a small lock was built by the Northwest Fur Company in 1797. In 1895 a lock designed to give 22 ft. depth was constructed at the Sault by the Canadian Government.

A further enlargement of the Welland Canal to a depth of 25 ft., with locks for 30 ft. depth, is now approaching completion.

These improvements to navigation on the St. Lawrence route represent a capital outlay of about $250,000,000.

Citizens of the United States have enjoyed the use of the Canadian canals and the St. Lawrence River on the same terms as Canadians themselves, and for the past twenty-five years American vessels have been free from the payment of tolls, maintenance and operation costs being entirely borne by the Canadian Government.

Canadian National Railways

MONTREAL HARBOR SHOWING LOCKS OF LACHINE CANAL

TRANSPORTATION PROBLEMS

The comparative transportation disadvantages of the midwest states, due to railway conditions and the opening of the Panama Canal, have created an insistent demand on their part for better and cheaper facilities for reaching the Atlantic seaboard. The idea of extension of ocean navigation to Chicago and the lake ports via the St. Lawrence has therefore very strongly appealed to them. Hence the present proposals for further enlargement of the St. Lawrence canals is an international undertaking.

There appears to be an impression in some quarters that Canada is unreasonably delaying the realization of this ideal. The reasons why the proposals are not regarded with enthusiasm in Canada are, however, fundamental.

Canada's railroad facilities are well ahead of population and production, and will be for years to come. Our problem is not to obtain relief from traffic congestion, but to find traffic sufficient to make existing transportation facilities pay their way. Over 22,500 miles of railway in Canada are nationally owned, representing a capital investment of over fifteen hundred million dollars.

The existing St. Lawrence waterway fully meets present waterborne traffic needs, and is of such capacity as to take care of any prospective traffic for many years. With a working capacity of about 20,000,000 tons per annum, the total tonnage of through freight in 1926 was about five and one-quarter million tons. About 900,000 tons of way freight was handled in addition, but this was largely local business of the port of Montreal confined to the Lachine Canal, which is provided with a double set of locks throughout, greatly increasing its capacity beyond that of other canals of the system. Eastbound freight largely predominates and is the governing factor, but it may be fairly stated that the present use of the canals is less than half their capacity.

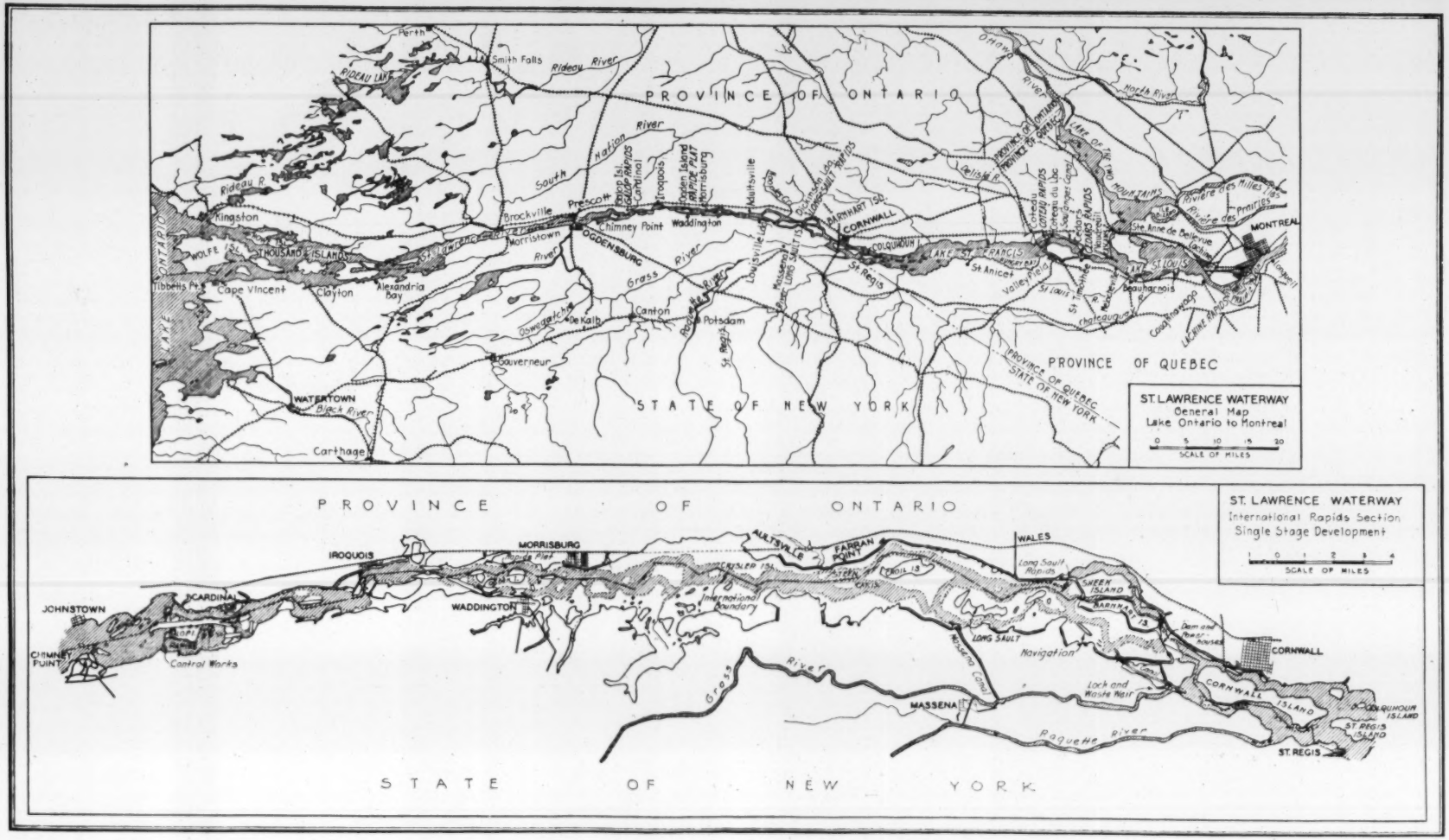
The proposed St. Lawrence deep waterway has been compared with those great interoceanic canals, the Suez and Panama. Each of these reduced the travel distance on highly important world-trade routes by about 8000 miles. Moreover each of these canals is a source of very large direct revenues from the levying of tolls. The Panama Canal, if the present rate of charges is maintained, will not only pay all operating expenses but in a comparatively short time will recoup the entire cost of its construction, as the original Erie Canal did.

On the St. Lawrence there now exists a highly efficient system of water carriage which has been operated free of tolls for the past twenty-five years. The imposition of tolls on a 25-ft. canal sufficient even for maintenance and operation would defeat the object of the improvement. No direct revenue can therefore be looked for, and the benefits to be derived are restricted to possible savings in cost of carriage and resultant expansion of production and industries.

CHARACTER OF TRAFFIC

The enormous volume of commerce on the Great Lakes has often been cited as an example of the influence of deep waterways in creating traffic. On the contrary, it may fairly be said that the existence of large bodies of iron ore on the south shore of Lake Superior forced the development of the navigable waterway to bring the iron and coal together, and today these two commodities constitute over 80 per cent of the Sault Canal traffic.

On the St. Lawrence no such conditions exist. The bulk of



MAPS OF THE ST. LAWRENCE WATERWAY

These two maps, redrawn from those presented in the report of Joint Board of Engineers, November 16, 1926, show the section of the river between Lake Ontario and Montreal and an enlargement of the International Section. In the enlargement the present banks of the river are shown by dotted lines and the present surface of the river is cross-hatched. The outer shore line shows how the river banks will be changed if the proposed dams are built.

the traffic between Lake Ontario and Montreal consists of grain, coal, and pulpwood. Canadian pulpwood is shipped westward to both United States and Canadian mills, while the American coal from lake ports moves eastward. Transportation of export grain, however, furnishes the bulk of the entire traffic of the canals. In 1927 there was exported through the port of Montreal 195,000,000 bushels, of which 178,000,000 passed through the canals.

The volume of eastbound through traffic in 1926 was 1,460,000 tons greater than in 1913. The increase in volume of grain traffic was 1,830,000 tons. Apart from grain the volume of traffic in 1926 was actually 370,000 tons less than in 1913.

Ninety-six per cent of all eastbound shipments from Canadian ports consists of grain. Considerable quantities of American grain are exported via the St. Lawrence, but the trade is fluctuating in character. Corn, which at one time used the route, has practically disappeared altogether. In 1921 nearly 28,000,000 bushels were exported through Montreal. Last season only one cargo of 137,000 bushels left the port, while nearly 5,000,000 bushels of Argentine corn were imported and distributed to points along the waterway, one and a half million bushels passing up through the Welland Canal.

For any material increase in the volume of Canadian traffic on the St. Lawrence Canals, whether 14 ft. or 25 ft. in depth, we must look to expansion of grain exports from the Northwest Provinces. This is more or less problematical. Extensive export shipments are already being made through the Pacific Coast ports, Vancouver and Prince Rupert. The Canadian Government is now engaged in the development of an eastern outlet through Hudson Bay which will provide an ocean route to Liverpool a thousand miles shorter than that via Montreal. The influence of these new competitive routes has yet to be ascertained, but certainly does not tend toward expansion of the St. Lawrence grain trade. Vancouver and Prince Rupert handled nearly 50,000,000 bushels of Canadian export grain last year.

Possible Savings in Cost of Carriage

Theoretical calculations based on comparative distance and time of travel have been made to show a possible reduction in cost of transportation of grain from the head of the Lakes to Liverpool of 8 to 10 cents a bushel by direct carriage in ocean vessels. Their futility is apparent, when to effect such a saving vessels would have to carry cargoes from Duluth and Fort William to Liverpool for less money than they now earn from the port of Montreal.

Rates out of Montreal in 1927 averaged about 8 cents a bushel, and from Fort William to Montreal were from 5 to 8 cents a bushel, transfer charges being absorbed in the rates quoted.

Careful survey and study of existing conditions on the route lead to the inevitable conclusion that so far as Canadian trade is concerned, no savings in cost of carriage can be effected which would be in any way commensurate with the cost to Canada of the undertaking.

Considering the present proposals in the light of an improvement of navigation of the river between Montreal and Lake Ontario, the situation may be fairly summed up by saying that neither the volume of Canadian traffic, actual or prospective, nor any possible savings in cost of transportation, in view of the capacity, efficiency, and economy of existing facilities, and taking into consideration our heavy railway investment and commitments to the development of other transportation routes, would warrant the necessary expenditures being made at the present time.

Improvements Now Claiming Attention

The improvements to navigation of the St. Lawrence which are now urgent are those between Montreal and the seaboard. Owing to the effects of channel dredging, decrease in run-off, and diversion of water from the Great Lakes, the results anticipated from the 30-ft. ship channel have not been fully realized. The prevailing levels in Montreal Harbor are now about three feet lower than formerly. Vessels leaving the port in low-water periods, which occur at the height of the navigation season, have been restricted at times to 26 ft. loaded draft.

The size of vessels entering the St. Lawrence trade is constantly increasing. Some of the regular liners plying to Montreal have a loaded draft of more than 34 ft. Vessels now under construction are specially designed to operate in the present channel on a reduced draft, but capable of loading to greater depth when the channel permits.

Measures are now contemplated to effect an amelioration of conditions between Lake St. Peter and Montreal by the construction of compensating works which are expected to raise the water level in Montreal Harbor two feet. This at best can only afford some temporary relief, and in the very near future the problem must be faced on constructing permanent works in the lower river above Quebec whereby a channel depth of 40 ft. will be made available throughout the navigation season.

Canadian National Railways

SHIPPING IN MONTREAL HARBOR

Combined Navigation and Power Development

The situation as regards improvement of the St. Lawrence has been greatly complicated by the demand for development of the water powers along the river.

Between Lake Ontario and Montreal it is possible to develop nearly five million horsepower, about two million on the international section and the remainder within the Province of Quebec. Approximately four-fifths of the aggregate will thus be in Canada.

The objective now sought to be attained, as stated in the reference to the International Joint Commission, is "the combination of navigation and power interests to obtain the greatest beneficial use of the waters of the river."

It is recognized that the interest of navigation is paramount. Effective utilization of the water for power during the summer months will therefore be restricted by control of water levels in the interest of navigation. During the winter some loss of effective head will be caused by ice accumulations. Under natural conditions the loss of head due to this cause at the Long Sault is from 12 to 18 ft., at the Soulanges from 10 to 15 ft., and at the Lachine about 11 ft. These conditions will be greatly bettered. The International Board of Engineers in their report conclude that the ice problem can be satisfactorily met and

stable winter conditions established with minimum loss of power head, by increasing the cross-sectional area at points where required, in order to secure an ice cover early in the season, thus reducing the area of open water, and consequently the formation of ice.

The International Section

According to the recommended plans, the navigation works on the International Section are to be located on the New York side of the river. It is a logical sequence of this arrangement that these works should be owned and operated by the United States.

Two plans of improvement of this section of the river are under consideration. One of these calls for utilization of the full effective head to be derived from the Lake Ontario level at a dam to be erected at the foot of the Long Sault Rapids, 116 miles below the lake.

The other plan provides for a lower dam at the same point, and a second regulating and power dam at Crysler Island, 17 miles upstream.

The single-stage plan involves very extensive land damages. Beneficial use of the river in this instance has been construed as the obtaining of the maximum use of the water for power, without regard to vested rights of riparian owners.

In the development of power on the Niagara River, preservation of the scenic beauty of the falls has been placed above all other considerations. The drowning of 30,000 acres of fertile lands, along a stretch of 30 miles of the St. Lawrence, in a populous and old-settled community, could only be justified by an absolute necessity, which in this case does not exist. It is perfectly feasible to avoid such a wholesale destruction by projecting the Lake Ontario level only as far as Point Iroquois, at mile 78, substituting a dam at this point for that proposed on the Crysler Island site. By construction of a guard lock for 14 ft. draft a mile above Iroquois, the present 14-ft. canal system could be retained unimpaired. Even with the 25-ft. waterway in operation the parallel 14-ft. canals will be a valuable adjunct which would postpone, probably for many years, the necessity for expensive duplication of locks on the larger waterway, and by accommodating the smaller vessels would not only obviate delays to traffic, but give greatly increased capacity which would be very valuable during congested periods.

The Canadian Section

Between Cornwall and Montreal, a distance of 67 miles, in which there is a fall of 133 ft., the river is in Canadian territory.

The possible power development is approximately three million horsepower, two-thirds at the Soulanges and one-third at the Lachine Rapids. The proposals provide for immediate development of 400,000 hp. on the Soulanges Section and 425,000 hp. at Lachine. In each case to obtain this partial development, a dam across the whole river must be constructed at once to meet the navigation requirements.

The effect of this method of improvement, forced by the necessity of providing a deep waterway for navigation, is to seriously increase the cost of the initial power developed in Quebec. Excluding purely navigation costs the cost of initial power, based on the estimates of the International Board of Engineers would be:

International Section.....	$120 per hp.
Soulanges Section.....	$245 per hp.
Lachine Section.....	$256 per hp.

This assumes absorption of St. Lawrence power in the province of Quebec at the rate of 40,000 hp. per annum. It is expected that in Ontario power absorption from the Long Sault will proceed at the rate of 75,000 hp. per annum.

If power development were the only objective at the present time, the construction of the international dam, giving each country a million horsepower, would naturally have precedence, leaving the more expensive developments in the Canadian Section to come into use following the absorption of the first block of two million horsepower.

The construction of a deep waterway concurrently with power development must necessarily result in saddling a heavy burden of cost on the powers in the Canadian Section.

It has even been suggested in some quarters that power should bear the whole cost of the joint undertaking, whereby the West would obtain free of cost a deep-water navigation from the Lakes to the Atlantic, at the expense of the power users of New York, Ontario, and Quebec.

The rate of power absorption from the St. Lawrence in Quebec has been estimated at 40,000 hp. per annum. The province is very richly endowed in water-power resources, and many sites are available throughout the province, where power developments can be cheaply made in blocks of a size to be attractive commercially. In recent years there has been rapid expansion of the basic industries of pulp and paper making and mining. To neither of these are the St. Lawrence power sites attractive, and the utilization of the power generated there must depend on the establishment of new industries.

Discussion of the St. Lawrence project in Canada has proceeded along broad lines indicating a strong spirit of neighborly amity and good will. It can, of course, hardly be expected that this feeling will reach such altruistic heights as to induce us to sacrifice national interests, or to incur heavy expenditures without at least fair prospects of some compensating gains.

With regard to the power phase of the proposals, the feeling may be said to be general that Canada should heartily cooperate in measures necessary to make available to citizens of the United States their full share in the power resources of the St. Lawrence. So far as the further deepening of the waterway and the construction of the necessary locks and dams throughout are concerned, many Canadians feel that, while an ultimate necessity, the time is not ripe for so gigantic and costly an undertaking with present traffic conditions and prospects and in view of other commitments and the heavy burden of taxation incurred during the war.

Negotiations now pending between the two countries and which are being conducted in a spirit of equity and strong friendship on both sides, will no doubt eventually result in agreement upon a course of action consistent with the best interests of both nations.

St. Lawrence Power

By JOHN P. HOGAN,[5] NEW YORK, N. Y.

WHAT is the present status of the St. Lawrence development? There are several different St. Lawrence proposals. There are the navigation development alone, the power development alone, and the navigation development with power as an incidental. The navigation development per se is an economic and political question with which we are not at present concerned. However, the statement is frequently made that if a canal be built for navigation, the power that can be developed at the various navigation dams will be sufficient to pay for the whole enterprise and even to return a handsome additional profit. If this be so, then the power alone without any navigation must be a profitable enterprise. The author will therefore

[5] Mem. Parsons, Klapp, Brinckerhoff & Douglas. Mem. A.S.M.E.

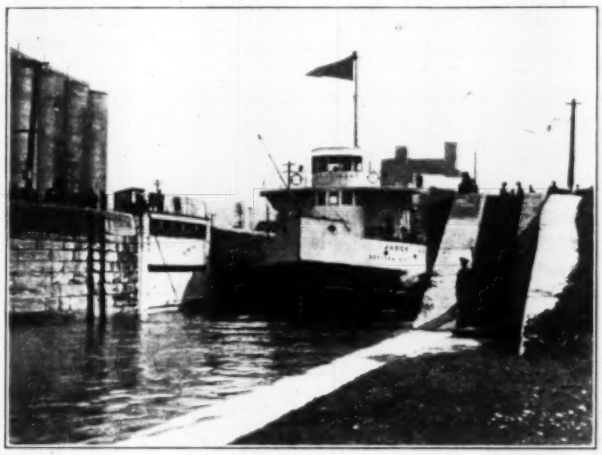
consider only the economics of independent power development without considering any expense borne by navigation.

ESTIMATED COST OF POWER

Of the power projects, the cheapest is a single-stage development at Barnhart Island with a head of about 83 ft.

For an initial installation of one-half the ultimate, or 1,200,000 hp., delivering an average of 900,000 hp. at 75 per cent load factor, the cost would be about $130,000,000. The annual charges would be about $25,000,000 to deliver about 600,000 kw. per annum or 5,000,000,000 kw-hr. The cost of this energy, including interest at 8 per cent and taxes, would be about 3 mills at the site, equivalent to about $20 per continuous hp., and 5 mills at the point of farthest delivery.

For the final installation of 2,400,000 hp., equivalent to a



Canadian National Railways

LACHINE CANAL, MONTREAL, QUEBEC, CANADA

delivery in the power market of 10,000,000,000 kw-hr. per annum, the annual charges would be about $35,000,000, including transmissions. The cost at the site would be about 2¼ mills per kw-hr., equivalent to about $15 per continuous hp., and about 4 mills per kw-hr. at the point of farthest delivery.

There is no question that continuous power ranging from $20 downward to $15 per horsepower-year can be advantageously employed in some quantity in continuous industries, at the site. The utilization of nearly 2,000,000 continuous hp. would, however, require industrial investment of several billion dollars and, with business prudence, could be successfully accomplished only over a period of years. Such industries could not afford to carry the burden of interest charges on idle investment during a period of partial use.

FEASIBILITY OF DISTRIBUTION OF SURPLUS POWER

It would therefore be necessary to distribute at least the remaining capacity of the initial installation in the general power market. The questions are, first, can this be done? and, second, can it be done economically?

Economically, new hydroelectric power, no matter how low the cost, cannot displace existing hydro, and the only markets that exist for St. Lawrence power are the existing steam-electric markets or growth of all markets. It is estimated that the growth of markets that can be reached by St. Lawrence would absorb from 100,000 to 150,000 hp. a year, which is altogether too slow a rate.

There remains only the alternative of shutting down an equivalent capacity of operating steam plants in order to permit the immediate absorption on a 75 per cent load factor of the greatest possible amount of energy. Under such a program, the capacity of the initial development could be absorbed by the existing steam-electric markets of New York, New Jersey, and New England by 1935, and the steam equipment rendered idle could be put back into service by growth of load about three years later. The annual load factor of such a system as the New York Edison would be reduced by such a program from about 38 per cent to 30 per cent.

If the entire 2,400,000 hp. from St. Lawrence were to be absorbed by the steam-electric markets and their growth, this might be accomplished between 1940 and 1945, and by that time the idle steam capacity could be reabsorbed by growth of load in about two years.

We are therefore confronted with a maximum program of from 15 to 20 years during which the utilities would be "holding the bag." However, development of continuous industries at the site and the demands of the Niagara district for additional power should accelerate the period of absorption, improve the conditions under which the power would be absorbed, and therefore materially reduce the burdens on the utilities.

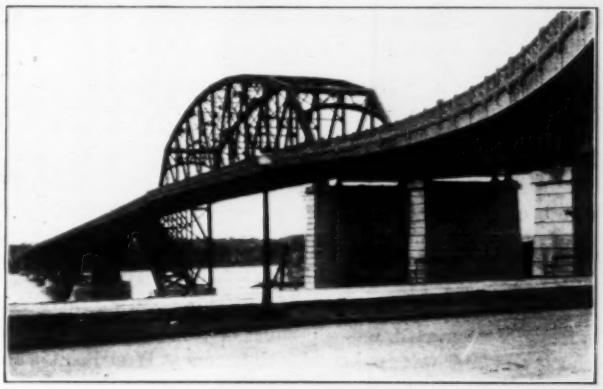
ECONOMIC RESULTS FOR THE PUBLIC UTILITIES

What would be the economic results for the utilities?

The expenses in addition to the actual cost of power would be:

1 Increased expenses due to lowering steam load factors
2 Interest, maintenance, and deterioration on idle steam equipment for not to exceed three years
3 Expense of putting the current on the switchboards of existing stations, which would be very heavy in metropolitan sections.

We may state definitely that with the present price of steam-



Underwood and Underwood

PEACE BRIDGE BETWEEN CANADA AND UNITED STATES AT BUFFALO, N. Y.

electric energy and improvements immediately in prospect, the utilities would be lucky if they broke even on the initial installation at the cost of 5 mills per kw-hr. delivered at the city limits.

With the cost decreasing to about 4 mills per kw-hr. for the final installation, there would be an apparent annual profit of about 1 mill per kw-hr. on ten billion kilowatt-hours, or about ten million dollars per annum, always if and provided that steam costs are not reduced an equivalent amount during the next 15 or 20 years.

It should be readily apparent that there is no gold mine in this for the utilities. In addition to the financial risk, they would have the following disadvantages to contend with:

1 Increased cost in earlier stages

2 Decreased security due to dependence on distant sources and transmissions
3 Increased difficulties of operation, such as apportionment of the load, frequency, and voltage regulation.

The major advantages would accrue to the public and to the electrical industry at large rather than to the particular utilities. The advantages to the particular utilities would be:

1 Stability of power prices
2 Decreased amount of coal necessary and increased insurance against coal or transportation strikes.

The major advantages to the public and to the entire electrical industry would be:

1 The eventual development of enormous electrical industries at the site and consequent general benefit not only to the electric industry but to industries as a whole
2 Saving in coal consumption
3 The numerous savings due to general interconnection which cannot readily be assessed in dollars and cents but which in the aggregate form a very considerable total and are, in fact, the basis of much of the progress in the industry during the past 10 years. These benefits are passed on to the public by rate regulation
4 The advantage of having the development properly designed, economically built, and properly marketed.

The author would have it understood that he is not laying down or advocating a particular method of development of the St. Lawrence and marketing of St. Lawrence power. He is merely advancing a possible method of development and discussing the results which might be attained.

The conclusions which he has reached after some years of careful study of this problem are that the proper economic development of the St. Lawrence powers would require the close, unselfish cooperation of all the utilities within reach over a long period of years, without any expectation of profit other than a reasonable return on the investment.

The profit, if any, would accrue to the electrical industries which might be located at the site, and, at the prices at which the power can be furnished, would not be more than sufficient to cover the business risk and to enable them to compete with similar industries in other parts of this country and abroad.

Difficulties in the Way

The principal difficulty that we have to contend with is the difficulty of getting the public mind to bridge the gap between an enormous quantity of wholesale power developed for 3 mills at 100 per cent load factor 350 miles away, and the delivery to the consumer, at an annual load factor of 5 to 10 per cent of the particular supply of power that he wants at the particular time he wants it, which is usually between 5 and 6 o'clock in the evening.

The costs of transmission and distributions, conversions and reconversions, and the consequent losses are unknown or forgotten, and if the author were to state to a lay audience what he now states, namely, that the development of St. Lawrence power would have a negligible effect on retail power costs throughout the territory in which it was delivered, there would be many who would say that he was inspired by the utilities to make such a statement.

The Making of Business Executives

By EUGENE G. GRACE,[1] NEW YORK, N. Y.

YOU have asked me to speak on what kind of training is required for engineers in order to equip them to become successful business executives. My first impulse is, therefore, to ask who are some of the engineers of our time who have become great business executives. Let me name some of those who come to mind.

Some Outstanding Engineer Executives

General George W. Goethals, at whose death a few days ago so many of us grieved, was a product of New York City public schools and later was graduated with honors at West Point. He was picked to become chief engineer of the building of the Panama Canal, one of the greatest engineering achievements in history, spending hundreds of millions of public money, always with efficiency and economy. What was General Goethals' outstanding characteristic? Ability to organize and direct the activities of men—a genius at administration.

General W. W. Atterbury, president of the Pennsylvania Railroad, largest transportation enterprise in the world, an executive compelled to think in terms of every phase of engineering—civil, mechanical, metallurgical, electrical, steam, commercial, human. You will remember Kipling's lines addressed to Captain Bob Evans, the famous naval officer of the Spanish War:

> Zogbaum can handle his pen, and I can take care of mine,
> But you can handle ten thousand tons skyhooting through the brine.

Kipling marveled at the feat which this naval captain performed; what shall we say of a man capable of directing the energies of an army of 200,000 human beings, and wisely guiding the trusteeship for $2,500,000,000 worth of property representing the savings of tens of thousands of men and women? And what is Atterbury's outstanding accomplishment? Ability to think clearly and quickly; and to decide and act; genius for organization, believing in organization, able to command the loyalty and enthusiasm of those whom he leads and inspires.

Herbert Hoover, a mining engineer, practicing his chosen profession in many parts of the world, ready for service to humanity and which he so ably gave at the very outbreak of the World War when the invasion of Belgium by the German Army called for some one to organize the feeding of the Belgian people. What is Hoover's distinctive quality? Ability to command the loyalty and confidence of the men who serve under him, a scientific approach to the study of business problems, and vision in foreseeing what needs to be done.

John Hays Hammond, again a mining engineer, attaining his greatest engineering eminence as a consultant for Cecil Rhodes in South Africa. Along with his professional efforts, John Hays Hammond became a great world citizen and ably represented this country on various diplomatic missions. What, then, is his most notable characteristic? Mr. Hammond is, above all, a philosopher, seeing big things in their proper mutual relations, thus enabling him to become, in the highest sense of the word, a business statesman.

May I call attention to one other name entitled, as I believe, to be mentioned among the outstanding engineers of our time?

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[1] President, Bethlehem Steel Company.

Address delivered before the Engineers' Society of Western Pennsylvania, Pittsburgh, Pa., January 30, 1928.

This man is not a college graduate; he obtained his engineering insight and skill in the hard school of rugged experience in steel mills, working in the ranks alongside the man in overalls—Charles M. Schwab. Beginning work right here in Pittsburgh, just fifty years ago, always amazingly energetic and active, full of dreams and visions, yet practical and sound; arriving at an early age to the highest executive office of the largest steel company in the industry, and 25 years later as president of the American Iron and Steel Institute, still leading.

I have known Mr. Schwab and loved him deeply for upward of a quarter of a century. It has been my privilege to be associated with him in the daily conduct of business perhaps more closely than any one else. His vision, his boundless optimism, his overflowing good humor have been a source of inspiration to me, as they have to so many others. What is Mr. Schwab's most characteristic quality? I would say that it is twofold: First, his ability and willingness to delegate authority to subordinates, and, having delegated that power, his insistence that they exercise it. Second, his desire to see other men advance and make money. I have never seen a man who took such enthusiastic delight in seeing those around him happy and successful.

Opportunities in Commercial and Human Engineering

In the careers of the men to whom I have referred we find typified the development of the chief problems of engineering. The first is to shape and direct the forces of nature and thus to bring the world's resources to add to the comfort and welfare of mankind. That, in a word, is the problem of production. Engineers have made a supreme contribution to the solution of that problem. But I feel that we have two somewhat newer branches of engineering which must command more and more of our attention. Those are what might be termed commercial and human engineering. Of what value is all our efficiency in production if we do not distribute efficiently, economically, and effectively? And of what value is any of it unless we can add to the happiness and deeper satisfaction of those engaged in industry, as well as those who enjoy its products?

I predict that the outstanding advances in business over the next ten years will be in improved merchandising and distributing methods. Herein lies a wide field of opportunity for the engineer.

Importance of Sound Judgment

We have briefly reviewed certain qualities of engineers who have become successful business executives. Is it possible for us to say that the material success of all of these men was due to any one characteristic common to each one of them? Indeed, I venture to assert that there is one quality which, in the last analysis, is determining as to whether any man shall realize material success in this world of ours. That quality—so notable in the character of each one of the men I have named—is sound judgment.

Moments arise in every life when it is necessary to say "yes" or to say "no" to a particular proposition or to a proposed line of action. It is the man who says "yes" at the proper time and "no" at the proper time who, in the final analysis, realizes business success. The ability to do this wisely is the mark of sound judgment, and such ability is necessary in a business executive.

I have known many business men seemingly slow in their mental processes, possessed apparently of little imagination and of none of the flair which gives fascination to so many characters, and yet who, when crises come—be they big or be they little—are able to so steer their business courses that they move in the right direction instead of into shallow waters or upon the rocks of trouble.

What is the basis for sound judgment and what makes a man able to judge wisely? Is this ability capable of development and training?

He Judges Wisely Who Observes Accurately

It seems to me we generally find that the man who judges wisely is usually the man who has observed accurately in the first place. He has seen and analyzed correctly that which has passed before him. He has reasoned out in his own mind the relationships of the things which he has seen; he has noticed the effects which have followed from causes which have come under his own observation—and he has seen these things straight. And that is the most difficult thing in the world to do!

If I were to prescribe one process in the training of men fundamental to success in any direction, it would be thoroughgoing training in the habit of accurate observation. It is a habit which every one of us should be seeking ever more to perfect.

Those of us who are engaged in large business undertakings know that there is nothing of more importance in enabling us to make wise decisions on policies which come before us for review every day, than our ability to obtain accurate information from the men under us. How often do men come to us in perfect good faith making reports concerning facts or events, when we are able to know, even without having the primary facts, that the information we are receiving is inaccurate, not because the man does not believe his information to be accurate, but because he does not know how to see clearly and precisely.

Will you think I am venturing upon a field which has no relationship to the subject before me if I make a suggestion which might well be considered by the educational authorities of our country? And that is this: From the moment children begin their studies in the grammar schools, even in the lowest grades, give them daily some training in accurate observation. Even in our colleges I think it would be wise if the students were called upon to devote a certain amount of their time regularly to a definite exercise in the practice of observation.

I think we all fully realize that accuracy is fundamental in technical education. We deal in weights and measures. We must be accurate. There can be no guesswork in the design of a structure to carry a load or in the design of a machine to develop or exert a required amount of power. This is a basic principle underlying the education of the engineer. Because of the character of his training it tends possibly to a narrowness in his education, and it therefore should be supplemented by cultural and business courses.

Industry's Responsibility to Afford Wider Opportunity to the Engineer

I believe, too, that upon our industries rests a responsibility for affording opportunity to the engineer, particularly the younger man, to supplement his school training and broaden it so that ultimately he will be fitted for the assumption of executive duties. In our own company we have worked out a comprehensive plan for initiating this. Each summer Bethlehem accepts for a ten weeks' probationary observation course a number of college graduates, most of them engineers, who have just completed their courses and who contemplate permanent employment with us.

The course is conducted for the twofold purpose of giving serious applicants an opportunity to become familiar with Bethlehem's entire range of operations, including the manufacturing and selling ends of the business, before deciding in which branch they desire to develop, and for giving the management opportunity to judge of the fitness of the young men to enter the company's employment.

Officers of the corporation and plant executives, in daily ad-

dresses to the entire group, present fundamental facts underlying the conduct of the business. Plant work is assigned and every probationer is expected to perform manual labor. Questions and problems which develop in the course of the work are discussed with the department superintendents.

Not only is the hard work, in humble jobs, a test of these young men's endurance, but it serves to give them a background of sympathetic understanding of the workman's point of view which enables them as executives in later years to strike a just balance between their duty to the corporation which employs them and to the men who work under their direction. It further serves to give them an insight into all branches of the business at the very start of their careers.

An essential element in this observation course is the requirement that these young men shall write in good, clear English an account of what they see from day to day and what it means to them. This training in the art of accurate expression thus becomes an important adjunct to the training in observation itself. And I may add that in my judgment few things are of more importance to us engineers than to learn something at least of the art of the use of effective English—and the better we use it the better executives we shall make.

Scientific Approach to Problems of Industry

Just here may I ask a question which perhaps I should have asked at the outset: What is an engineer? Wherein does the equipment of the engineer differ from that of any one else? If I could sum it up in a word I should say it consists in a scientific approach to the problems of industry. By that I mean that one shall not decide questions upon a hit-or-miss basis, but rely upon exact information, calculated in the light of established principles and relations. Mr. Schwab likes to tell a story which, it seems to me, illustrates well the change which has come over modern business as distinguished from the business methods of half a century ago.

When steel rails were first made in this country the specifications were largely based upon guesswork. One day the Carnegie Steel Company received from the Pennsylvania Railroad a new set of specifications calling for an exact chemical formula in the composition of the rails. Captain Bill Jones had struggled with these specifications and found it very difficult to make the rails to meet them. He finally came to Mr. Schwab one day in a state of great despair and said: "Charlie, this damned chemistry is going to ruin the steel business." Today all sound business is conducted on a basis of scientific knowledge, and the engineer has made the greatest contribution to that fund of knowledge. And the reason why the engineer has made so great a contribution is because he has been trained in making his approach to business upon a scientific basis.

Some engineers emphasize the purely scientific aspects of their work without relating it to the broader fields of its practical application. Perhaps that is one of the reasons why so many engineers have not realized the money rewards to which the creative character of their achievements entitled them.

Common Sense the Fundamental

George Gibbs was once asked what he thought should be the outstanding principle in the training of engineers in our colleges. His answer was characteristic of the man when he said:

> The thing which I learned in college which was of the greatest value to me in engineering was not so much the ability to calculate stresses, to design wheels, and experiment with the elemental problems of chemistry. These things many a man learns, and, learning no more, becomes merely a draftsman in an engineering office. What I found of value in college was the study of the fundamentals of knowledge and those other things which gave me some kind of training in the exercise of common sense.

Here, as George Gibbs expresses it, we have the most important secret of all, the ability to exercise common sense. Thousands of engineers can design bridges, calculate strains and stresses, draw up specifications for machines, but the great engineer is the man who can tell whether or not the bridge or the machine should be built at all, where they should be built, and when.

Every material thing in this life has an economic aspect, and there is always a question as to whether or not a thing should be built which is scientifically or mechanically perfect, or whether it should be built in a manner to serve the purpose required. It is so often necessary to determine whether any machine or any engineering project promises to be a commercial success, which is another way of asking the question of whether, if it is done, the necessary money will be forthcoming with which to pay for it.

These are very practical questions, calling always for the exercise of common sense and sound judgment. And there is no magic or legerdemain whereby we may acquire these qualities. They can only grow out of experience, and a man very often with apparently the most restricted environment can through accurate observation acquire a knowledge of a subject and a vision concerning its meaning which will equip him for supreme attainments as a business executive.

Perhaps you will think, therefore, that in coming to you to discuss the high-sounding title of the subject entrusted to me I conclude with something of an anti-climax when I tell you that the way we engineers can obtain the best possible training to equip us for success as business executives is to "watch our step," and keep stepping! Let us look at what is around us and look carefully. If we get the meaning of that which we are seeing from day to day and interpret that experience accurately, we are on the sure road to achievement. And if we go a little further as Steinmetz did, as Thomas A. Edison did, as Michael Pupin did, and not only see carefully what is around us and interpret it accurately, but are able then to project our minds into the field of the unknown, so that out of the seen we shall be able to gather a vision of the unseen, we shall then become truly great engineers and, perhaps, benefactors of mankind. For of such, I am proud to say, is the Kingdom of Engineers!

Submarine Salvage

IN THE February, 1928, issue of MECHANICAL ENGINEERING, p. 125, an article was published on submarine salvage. An article by the French submarine engineer Laubeuf gives some interesting European statistics as to the actual salvage results and the time it has taken to raise submarines.

The French submarine *Pluviose* lost at Calais on May 26, 1910, was not caught by chains until June 3, 1910, and refloated only on June 10. The English submarine *A-1* was lost at a depth of 13 m. (42.6 ft.) on March 18, 1904, right near the Portsmouth Arsenal. Notwithstanding its small size it was refloated only after a month had elapsed. The English submarine *A-8* was in two accidents. First, it went under on June 8, 1905, at Plymouth and was refloated three days after. The next time it sank on Feb. 2, 1912, in 14 m. (46 ft.) of water and was not recovered until Mar. 11. The French *Lutin* sank just at the outer line of the port of Bizerta in 36 m. of water (115 ft.), and was refloated 13 days after. In all of these cases the crews lost their lives. The *K-13*, an English 1800-ton submarine, sank in September, 1917, in the Clyde, and notwithstanding the fact that it was in a river and near well-equipped shipbuilding plants, it was not raised until 40 hr. after the accident.—*La Nature* (Paris), Apr. 15, 1928, pp. 358-359.

Competitive Purchasing and Evaluation of Proposals for Power-Plant Equipment

By L. B. BONNETT,[1] BROOKLYN, N. Y.

The author describes the procedure employed by the Brooklyn Edison Co., which, it is believed, encourages manufacturers to propose the best equipment they know how to build. It clearly indicates that excellence of performance has a definite and recognized value to the company, and stimulates the proposing of improved designs as soon as they are available. Further, it is believed to result in the fairest judgment of the merits of different proposals, and therefore in the purchase of the most satisfactory equipment for the physical conditions which have to be met.

IN EXTENDING power plants and building new ones, engineers strive to obtain the best possible results, taking into account both first cost and operating costs. After the general plan of design has been decided upon, perhaps the most important factor in its bearing on final results is the selection between different makes of the individual pieces of equipment that together make up the power plant. It is the belief in our company that prudent selections can best be reached when there is the freest and most wide-open competition among manufacturers. Where purchasing and engineering functions are separated, as they now are in most large companies, satisfactory results of such a policy are only possible through complete cooperation and mutual confidence and understanding between the purchasing and the engineering departments.

Our process of purchasing competitively interweaves through the two departments and may perhaps be divided into four parts:

1 The specifications prepared by the engineers
2 The obtaining of proposals under these specifications by the purchasing department
3 The evaluation of these proposals through the cooperation of both departments
4 The final closing of the purchase.

The Specifications

The specification is intended primarily to describe the operating results to be obtained, leaving just as wide open as possible to the judgment of the bidder the detailed methods by which this result is accomplished. This specification must, of course, define the limiting conditions, such as available space, maximum size and weight of parts, temperatures which can be handled, pressures, etc. Perhaps what is meant can best be illustrated by comments on the specification on which our last condenser was purchased. The first sentence of this is as follows:

> It is the intent and purpose of this specification that the manufacturer shall furnish, deliver, erect, and place in operating condition satisfactory to the Company, one surface condenser with auxiliaries and miscellaneous equipment as specified herein, for use with a 110,000-kw. turbine in the Hudson Avenue Station of the Company.

Information was included on the available space between foundation columns; the temperature of the circulating water, minimum, maximum, and average; the pumping head required, and the weight which may be carried on the turbine exhaust nozzle. A size of tubes was mentioned, but the bidders were invited to present alternatives if they so desired, and as a matter of fact the condenser was purchased with a different-size tube from that first specified.

One perhaps unusual feature was the complete omission of any requirement as to the square feet of surface or of any limitation on the number of passes. Instead, information was included from which the manufacturer could himself determine the best size and arrangement for his particular design. The turbine water rates with vacuum corrections were given, together with the value to the company of decreased coal consumption due to improved vacuum. The cost of pumping water was indicated so that the manufacturer could choose the proper balance between surface and water volume. The method of calculation from these data with an example was given to indicate just how we proposed to make comparisons of performance. With this as a basis, the manufacturer, knowing his costs of two different sizes of condensers with tubes, could work out for each size the fixed charges and the operating charges and so arrive at the most economical proposition for him to put in.

Such a specification, we believe, allows the widest latitude to all manufacturers to present the propositions which best fit their particular methods of manufacture and design, and hence gives us the broadest view of possible variations from which to choose.

Obtaining Proposals Under Specifications

These specifications are then submitted by the purchasing department to the manufacturers for proposals, with the request that these proposals be separated into two parts: first, the complete engineering proposal, including all performance guarantees as required by the specification, dimensions, and descriptive material necessary for us to form judgment as to the adequacy of the proposal; and a second part covering price and shipment on the material described in the first half of the proposal. While the proposals are being worked up, every possible opportunity is afforded the manufacturers for discussion with the company engineers so that our requirements may be clearly understood and the advantages of each manufacturer's design may be fully presented. When formal proposals come in, the engineering part is sent to the engineering department for study and evaluation in comparison with similar proposals from other manufacturers.

Evaluation of Proposals

It must be recognized that the selection of material to be purchased must be a matter of judgment and cannot be a matter of rigorous mathematical solution. However, the better informed the judgment and the more clearly seen the relative importance of different factors which go to make up one's preference, the more nearly correct the final judgment will be and the more nearly certain it is that the operating results will be the best possible under the conditions. We are all more or less predisposed to like certain kinds of equipment because we have had favorable experience with them, but such experience must not be allowed to blind us so that we fail to properly weigh improvements that others are making.

It has been our experience that if we form first our judgment of the relative advantages of different propositions from the engineering data only, without the price, we can with more free-

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[1] Purchasing Agent, Brooklyn Edison Co.

Presented at a meeting of the Metropolitan Section of the A.S.M.E., New York, November 10, 1927.

dom from prejudice weigh the advantages and disadvantages other than those expressed in actual performance guarantees. The process of asking oneself how much more in dollars one proposition is worth than another is conducive to careful thought to make certain that one's opinions have a sound basis of fact.

We believe it to be sound policy in comparing propositions to take the performance guarantees of reputable manufacturers at their face value without any corrections for probable or possible differing margins of safety which may be claimed. If a manufacturer desires to make a certain guarantee and then asserts that he has an extra large factor of safety, we are compelled to believe either that the factor of safety is mostly in the salesman's talk or that the company submitting the proposal has not the courage of its convictions. We expect to test, after installation, all equipment to see that it meets the performance guarantees, and so we expect the manufacturer to retain sufficient margin to cover the contingencies of manufacture which his experience has indicated necessary. We expect that the material when installed will either meet guarantees or be corrected by the manufacturer until it does come up to guaranteed performance.

Occasionally guarantees come in which are so far out of line with usual performance, sometimes better, sometimes worse, that apparently some error in calculation has been made. Such apparent errors or inconsistencies are of course called to the manufacturer's attention for correction or justification.

The basis of the mathematical evaluation of the performance guarantees is an estimated load-duration curve of the main unit, this curve being the amount of load plotted against hours of use. At best this load curve is only a crude approximation of what the machine will actually carry, since many of the factors which have a bearing on the hours' use of any machine are entirely indeterminate. For instance, what radical improvements may be developed and incorporated in the next unit, because of which the present unit becomes less useful for base-load operation? What troubles may occur, or what rearrangements of the station may be necessary, seriously affecting the division of load between units or between stations? However, despite the admitted inaccuracy of such a predicted load curve, if thoughtfully prepared it unquestionably is more accurate than just an offhand guess as to the average load and useful life of the machine.

Again, because of the inexactness of the premise, extreme accuracy in arriving at the annual and capitalized operating costs is unnecessary. It frequently happens that the obviously most efficient or most suitable machine is also the lowest in first cost, and after a preliminary inspection of the proposals a conference between the engineering and purchasing departments will settle the choice without question. In other cases where there are several bids, such a conference may show that some of the bids are obviously out of the running because of comparatively poor performance often coupled, strangely enough, with high price. With these eliminated, the remaining proposals become a subject of mathematical study of operating costs.[2] The results of such analysis indicate the capitalized advantage of one proposition over another due to better performance.

There often are factors on which only rough estimates can be made: for instance, one equipment may occupy much more space than another, and because of that cause changes in construction of other parts of the job which will increase cost or decrease convenience. The dollar value of this must be estimated. Duplicate equipment may reduce the value of spare parts necessarily held in stock. Such items are reasonably tangible. Unsatisfactory performance in the past will of course be a sound reason for the rejection of a proposal unless evidence is presented that the difficulties have been overcome. Any such reason for the elimination or serious handicapping of any proposition must convince one that it is based on fact and has been given no more weight than it deserves; otherwise it would be the means of completely destroying any open-minded consideration of improvements that are continually being made.

There are often minor factors of preference against which it would be almost impossible to assess a definite value, but an expression can quite properly be made of an unevaluated preference, other things being equal. This would have a very important bearing on the placing of the business if the prices as weighted by the evaluation factors are very close together.

When the performance calculations have been completed, the results are gone over in a conference between those responsible for operation, engineering, and purchasing, and final figures are agreed upon showing the comparative values to the company of the different propositions under consideration. They are conveniently expressed as excess charges against certain proposals.

The purchasing department then takes the quoted prices and, adding the evaluation charges, arrives at weighted figures of cost.

Considering also matters of purchasing policy, such as dependability of promises of shipment, time required for manufacture, reputation of the manufacturer for fairness in taking care of minor changes, and the encouragement of active competition, the proper disposition of the order becomes at once apparent.

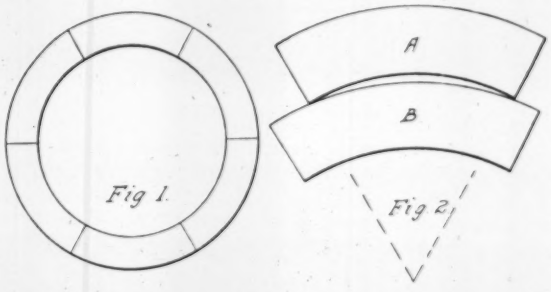
We feel that this procedure has the very definite effect of encouraging the manufacturers to propose the best equipment which they know how to build. It clearly indicates that excellence of performance has a definite and recognized value to us. It stimulates the proposing of improved designs as soon as they are available. We believe it results in the fairest judgment of the merits of different proposals, and therefore results in the purchase of the most satisfactory equipment for the physical conditions which have to be met.

[2] See "Engineering Analysis as Applied to the Selection of Type and Size of Power-Plant Equipment," by J. N. Landis, Trans. A.S.M.E., vol. 50, Fuels and Steam Power, May–Aug., 1928.

An Optical Illusion

THIS brief item is cited here as an illustration of how little reliability can be placed on visual comparison of sizes of machine parts unless checked up by actual measurement.

The figure on the left shows a wiring tie for sheet-metal



pails. The tie was of the sectional type, made of six equal sections. These pieces were first cut from the forged ring and afterward shaped on the sides and ends, the latter having an included angle of 60 deg. to make close-fitting joints, so as to obtain an unbroken ring at the finishing diameter. Two of the pieces happen to lay on the bench in the position shown at *A* and *B* in the right-hand side of the figure. They do not look as being either of the same length or of the same curvature, and yet they are exactly alike, as would be found by superimposing them upon each other. As the author states, this only goes to prove that the evidence of the eye may often be misleading. —J. Henderson. *Machinery*, vol. 34, no. 8, April, 1928, p. 645.

The Embrittlement of Boiler Plate

Causes of Embrittlement in Steam Boilers Resulting in the Formation of Intercrystalline Cracks—Laboratory Investigation of Cracking—Inhibition of Embrittlement By Feedwater Treatment

By S. W. PARR[2] and FREDERICK G. STRAUB,[3] URBANA, ILL.

WITHIN recent years a phenomenon of more or less frequent occurrence has become recognized, to which the term "the embrittlement of boiler plate" has been applied. Because of the relatively infrequent occurrence of this difficulty and the rather obscure causes which bring it about, the fact of embrittlement has been largely in question. However, both the evidence of its presence and the conditions which promote it are matters of paramount importance at the present time, because within recent years an increased number of boiler failures chargeable to embrittlement have occurred.

It should be noted at the outset that while the phenomenon of embrittlement is not new, there has without question been an increase in the number of cases where this distress has appeared. This has been a logical sequence of the present-day trend toward higher efficiencies, calling for higher pressures and cleaner surfaces, with a resulting impetus given to methods of water purification. Doubtless also a better comprehension and diagnosis of the difficulty has resulted in a seeming increase of the number of cases of embrittlement.

The historical development of the study of the phenomenon of embrittlement would undoubtedly show that many cases of boiler failure were laid to other causes than embrittlement in years gone by. The first indication the industry had that this type of failure was different from any previously encountered was in 1895 when a plant at DeKalb, Illinois, encountered cracking in drums which were installed in 1893. At that time the suggestion was made that the feedwater might be the cause, but small attention was given to it. In 1906 one of the authors described an unusual type of water and outlined an area where it occurred having Champaign-Urbana as a center and extending west as far as Bloomington, Illinois, and east as far as Veedersburg, Indiana.[4] This water was characterized by having free sodium bicarbonate present and an almost complete absence of sulphate. In 1911 a plant manufacturing caustic soda reported having difficulty in the form of cracking in the seams of the boilers. This plant used as part of its supply a water which was treated with soda ash and caustic, the sodium hydroxide in the boiler water being as high as 100 grains per gallon.

It was not until 1912 when a boiler operating on the unusual type of water above referred to exploded at Bloomington, Illinois (Fig. 1), that much attention was paid to this particular type of difficulty, suggesting a possible connection between the failures and the water employed.

In 1915, two boilers in the new power plant at the University failed and had to be replaced after less than four years of service. The University instigated an investigation which resulted in the publishing of its Bulletin 94. The fact that the fracture resembled that of brittle metal more than that of a perfectly ductile plate, as shown in Figs. 2 and 3, led to the use of the term "embrittlement" as descriptive of the condition the plate had acquired. The work published in Bulletin 94 demonstrates the fact that the sodium bicarbonate of these waters hydrolyzed to caustic soda and that concentrated caustic solution weakened steel. The main thing accomplished was that an apparent relation was shown to exist between this failure and alkaline waters. At the same time a remedy was not only suggested but was put in operation in the University power plant.

During the interval between 1916 and 1924 a number of investigations were made to determine the cause of embrittlement failures

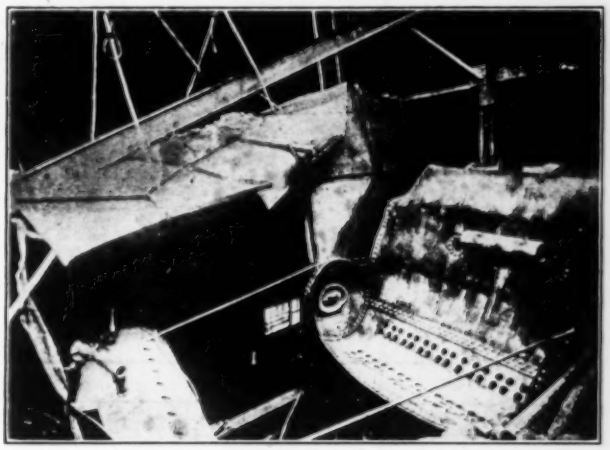


FIG. 1 BOILER EXPLOSION DUE TO EMBRITTLEMENT AS A RESULT OF USING FEEDWATER HAVING FREE SODIUM BICARBONATE PRESENT BUT NO SULPHATE

which were continuing to increase. The research conducted by the Babcock & Wilcox Company did much toward explaining the difficulty and bringing the issue before the boiler user. On the other hand, any suggestion that alkaline waters may have been a contributing agent was naturally opposed by water-treating companies which produced alkaline water as a result of their treatment.

OCCURRENCE AND CHARACTERISTICS OF CRACKS

A detailed description of some 300 cracked boilers from plants encountering difficulty in the form of embrittlement was given in Appendix B of Bulletin 155. Only a brief review of the type of cracking will be given here.

1 The cracks occur primarily below the water level.
2 The cracked plates have always been in tension and the cracks occur at points of high localized stresses.
3 Seams having factors of safety as high as 10 have encountered cracking.
4 The cracking is not confined to poor steel but occurs in steel of excellent quality as well as in steel not so good.
5 The cracking has occurred in seams in boilers built as late as 1924, and with seams being as well made as possible then.

[1] Presented at the Midwest Power Conference, Chicago, Ill., February 14 to 17, 1928. Published by permission of the Director, Engineering Experiment Station, University of Illinois, Urbana, Illinois.

[2] Professor of Applied Chemistry (Retired), University of Illinois.

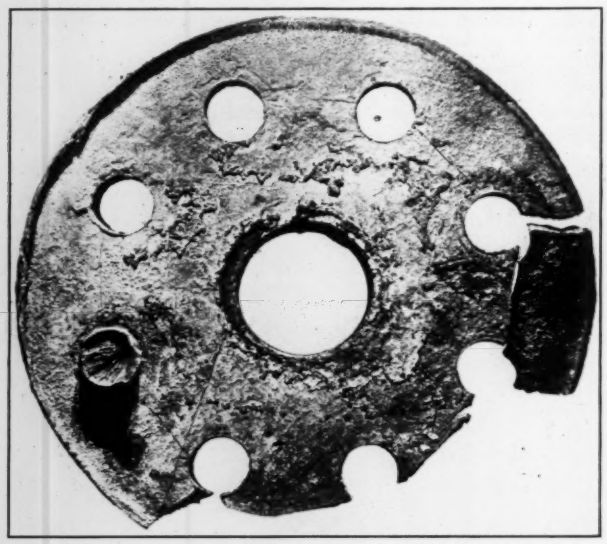
[3] Special Research Assistant, Engineering Experiment Station, University of Illinois.

[4] "The Service Waters of a Railway System," by S. W. Parr, *Jl. Am. Chem. Soc.*, pp. 640–646, 1906.

6 Both outside-calked and outside with inside-calked seams have cracked.

The characteristics of these cracks may be summarized as follows:

a They do not follow the line of what is generally considered the line of maximum stress.
b They start on the dry side of the plate.
c They run in general from one rivet hole to another, though they often run past each other, leaving islands of plate.
d They are irregular in direction.
e They never extend into the body of the plate beyond the lap of the seam.



Figs. 2 and 3 Boiler-Metal Fractures Due to Embrittlement

f There is no elongation of the plate.
g Rivet heads crack off or are easily dislodged.
h A microexamination of all the cracked plates reveals the fact that the crack progresses around the grain boundaries and is intercrystalline.

Water Conditions

A summary of the chemical conditions which characterize the water used in the boilers where embrittlement has occurred is as follows:

a Sodium carbonate is the one substance which is invariably present in the feedwater.
b Sulphate hardness is usually absent or low in respect to the sodium carbonate present. Sodium sulphate is similarly lower than the sodium carbonate.
c Boilers encountering this trouble used waters having characteristics noted under (*a*) and (*b*) and as a consequence of the chemical reaction in the boiler develop a caustic condition with sodium hydroxide in material excess over the sodium sulphate.

Recent Instances of Embrittlement

During the interval between June, 1926, and September, 1927, ten new instances of embrittled boilers involving some 25 different boilers were brought to the attention of the investigators. A rough compilation as to the cost of replacing or repairing these boilers showed that at least $150,000 was involved. In addition to cost one must consider the fact that in many plants the cracking had progressed so far that the lives of the operators were endangered.

These cases of difficulty occurred on boilers operating as low as 30 and as high as 250 lb. pressure and on different types of boilers, thus illustrating further that it is not confined to any one make or design of boiler. The cracks were confined to riveted areas, but occurred at random in practically any seam below the water line. Samples of steel from a large number of the cracked boilers were analyzed and tested, and no marked deviation from the original mill reports was evident. This confirmed the statement previously made that embrittlement is not confined to poor steel.

In all instances the boiler feedwater did not meet the A.S.M.E. recommendation as to sodium carbonate-sodium sulphate ratio. The sulphates were low in all cases.

In one instance the embrittled boilers resulted from the use of a natural water having a high sodium carbonate content with the sulphate low. Two plants were using the lime-soda treatment on low-sulphate waters and were overtreating with soda ash. Seven plants were using zeolite-treated water. The untreated waters were low in sulphate hardness and high in carbonate hardness, thus giving a water in which the sodium carbonate predominated over the sulphate. The figures show that 10 per cent of the difficulty occurred on natural waters, 20 per cent on soda-ash treatment, and 70 per cent on zeolite-treated waters.

In 1926 The American Society of Mechanical Engineers in their Boiler Construction Code called attention to the presence of embrittlement cracking and recommended definite sulphate-to-carbonate ratios to be maintained as a precautionary measure toward stopping this trouble. They included in this recommendation the following explanatory paragraph:

> Cracks of this particular character have not been reported in cases where water-softening equipment has been intelligently used, maintaining close control over boiler concentrations, and the boilers have been properly operated.

At the time this code was recommended this clause may have been warranted, but the data collected since appear to indicate that water treatment carried on as directed by the manufacturers of the equipment has resulted in the embrittlement of boilers. The concentration had been closely watched and the boilers were properly operated.

Causes of Embrittlement

To determine what is producing embrittlement in steam boilers it is essential that all contributing factors be given equal consideration. The four following factors have been carefully considered in each case investigated in trying to explain the cause of these failures.

a Material
b Workmanship
c Operation
d Feedwater.

The first three, material, workmanship, and operation, may have a large influence on the cause of embrittlement, yet they have never been found to be the same through all embrittled boilers. The material and workmanship in one embrittled

boiler may be bad, while in the next it may be excellent. Similarly a boiler operated very carefully at low rating may crack, while another may crack after heavy service.

On examining the mass of data collected from embrittled boilers one could not help but see that the type of feedwater used in embrittled boilers was apparently the only common factor. When the feedwater was analyzed it disclosed the fact that sodium carbonate was always present while the sulphates were much lower. The boiler waters showed the presence of a high alkalinity, with a corresponding small sulphate content.

Boiler feedwaters can be considered roughly under two heads, carbonate and sulphate. The former have the carbonates of magnesium or calcium in excess and have only a small amount of the corresponding sulphates. This has commonly been termed "temporary hardness," since it decreases on heating. The sulphates of calcium and magnesium are changed but little on heating, and have been termed "permanent hardness." In some natural waters in the United States sodium bicarbonate is present in appreciable amounts, and almost invariably the sulphates are low in respect to the sodium bicarbonate. On heating in the boiler the sodium bicarbonate breaks down to give the carbonate, which in turn decomposes to give sodium hydroxide and carbon dioxide.

$$H_2O + Na_2CO_3 \longrightarrow 2NaOH + CO_2$$

Water + sodium carbonate ⟶ sodium hydroxide + carbon dioxide.

The amount of the decomposition of the carbonate depends upon the temperature or steam pressure and the partial pressure of the carbon dioxide. In a boiler the steam carries away the carbon dioxide, favoring the formation of the hydrate. Boilers have been found where over 90 per cent of the sodium carbonate has gone over to the sodium hydroxide.

One thinks at once that all boilers have sodium hydroxide in them since soda ash is a common boiler compound. This is so, yet the amounts are in no case near those encountered in embrittled boilers, and furthermore the sulphates are present in large amounts. Table 1 gives the analyses of boiler waters

TABLE 1 ANALYSES OF WATER TAKEN FROM BOILERS HAVING HIGH SULPHATE CONTENT. NOT EMBRITTLED

Steam pressure carried, lb. gage	150	175	175	125
	Grains per U. S. Gallon			
Sodium hydroxide, NaOH	2	5.8	7.6	36.3
Sodium carbonate, Na_2CO_3	10	6.1	19.9	8.7
Total alkalinity as Na_2CO_3	13	14.2	30.5	59.5
Sodium sulphate, Na_2SO_4	200	42.2	71.5	102.4
$\frac{Na_2SO_4}{\text{Alkalinity as } Na_2CO_3}$	15.4	2.9	2.4	1.7

commonly encountered and shows the high sodium sulphate content.

If calcium or magnesium sulphates are present in the water, soda ash is added to form the less soluble carbonates and sodium sulphate.

$$Na_2CO_3 + CaSO_4 \longrightarrow Na_2SO_4 + CaCO_3$$

Sodium carbonate + calcium sulphate ⟶ sodium sulphate + calcium carbonate.

The sodium sulphate is increased so that an excessive amount of soda ash would be necessary to bring about an excess over the sulphate in normal permanent hardness. A water containing small amounts of sulphates could readily be changed to one in which the soda ash is in excess by soda-ash treatment, and such types have been found in use in embrittled boilers.

Thus sodium carbonate may be in the feedwater in excess of the sulphate by either one of two causes: first, in a well water having the sodium carbonate present, and second, as the result of water treatment. The addition of an excess of soda ash will furnish such water, or it may result from the use of the zeolite process of softening. This system of softening is accomplished by means of either a mineral or artificial zeolite. The bicarbonates of calcium and magnesium are converted to the bicarbonate of soda and sulphates of calcium and magnesium to sodium sulphate, thus furnishing a water with zero hardness. The zeolite is rejuvenated by treating with sodium chloride solution. This system when used on a water having a lower sulphate hardness than carbonate hardness will produce a water in which the carbonate of soda will predominate over the sulphate and resemble the waters used in embrittled boilers.

The districts in the United States where embrittlement has occurred in boilers using well waters containing sodium bicarbonate can be readily isolated. The map in Fig. 4 shows the location of these districts. Much effort has been recently directed toward modifying these natural waters so as to overcome the effect of the sodium bicarbonate, and the cases of embrittlement on these waters are apparently decreasing in

FIG. 4 DISTRICTS IN THE UNITED STATES WHERE EMBRITTLEMENT HAS OCCURRED IN BOILERS USING WELL WATERS CONTAINING SODIUM BICARBONATE

number. The increase in the use of water treatment on low-sulphate surface waters has brought about an increase in the use of soda-ash and zeolite systems of softening. Naturally, waters having too high a sodium carbonate content as a result of either of these systems of water treatment cannot be isolated in any districts, since low-sulphate surface waters occur in practically all sections of the country. As a result of this trend in water treatment the number of cases of embrittlement on these types of softened waters is increasing.

Table 2 gives the analyses of seven of the waters used in

TABLE 2 ANALYSES OF FEEDWATERS USED IN EMBRITTLED BOILERS

Steam pressure carried, lb. gage	200	250	200	30	225	265	225
Source of water	Lake	River	Lake	Well	Lake	Lake	Well
Treatment	Zeolite	Zeolite	Zeolite	Zeolite	Zeolite	Lime-Soda	None
	Grains per U. S. Gallon						
Calcium carbonate	0.15	0.00	0.00	0.0	0.20	0.41	3.16
Magnesium carbonate	0.10	0.00	0.00	0.0	0.29	0.41	1.98
Sodium carbonate	9.33	11.47	5.83	18.9	8.90	4.00	9.05
Sodium sulphate	2.23	10.30	1.63	2.0	1.50	2.10	0.12
Sodium chloride	1.10	3.18	1.25	1.6	1.50	1.34	10.50
Sodium sulphate / Sodium carbonate	0.23	0.90	0.28	0.1	0.17	0.52	0.01
Recommended A.S.M.E. ratio	2.00	3.00	2.00	1.0	2.00	3.00	3.00

embrittled boilers. This shows the type of water common to every embrittled boiler encountered. The first five represent waters which have been zeolite treated, the sixth soda-ash treated, and the last a natural sodium carbonate water. These show further that they have not met the A.S.M.E. recommenda-

TABLE 3 ANALYSES OF BOILER WATERS FROM EMBRITTLED BOILERS

Steam pressure carried, lb. gage	200	250	200	30	225	265	60
Source of water	Lake	River	Lake	Well	Lake	Lake	River
Treatment	Zeolite	Zeolite	Zeolite	Zeolite	Zeolite	Lime-Soda	Zeolite
	Grains per U. S. Gallon						
Sodium hydroxide, NaOH	85.4	24.3	216.0	25.6	63.2	99.2	51.2
Sodium carbonate, Na_2CO_3	69.2	10.5	74.9	25.5	11.3	25.9	12.4
Sodium sulphate, Na_2SO_4	44.7	36.2	56.6	13.3	14.9	82.6	3.6
Sodium chloride	27.3	24.4	87.5	33.9	18.7	45.0	...
Total alkalinity as Na_2CO_3	188.0	44.5	361.0	61.1	94.8	164.9	84.1
$\frac{Na_2SO_4}{\text{Alkalinity as } Na_2CO_3}$	0.24	0.81	0.15	0.21	0.15	0.50	0.04
Recommended A.S.M.E. ratio	2.0	3.0	2.0	1.0	2.0	3.0	1.00

TABLE 4 ANALYSES OF BOILER WATERS TREATED TO INCREASE THE SULPHATE-CARBONATE RATIO

Source of water	Well	Lake	Lake	Lake	Well
Treatment	Lime and acid	Zeolite and acid	Zeolite and acid	Zeolite and acid	Lime and aluminum sulphate
	Grains per U. S. Gallon				
Sodium hydroxide (NaOH)	22	28.2	22.0	36.3	14.1
Sodium carbonate (Na_2CO_3)	9	5.3	15.4	14.6	17.0
Sodium sulphate (Na_2SO_4)	90	89.8	116.1	119.7	72.8
Total alkalinity as Na_2CO_3	38	42.7	46.2	55.4	36.6
$\frac{Na_2SO_4}{\text{Alkalinity as } Na_2CO_3}$	2.4	2.1	2.5	3.1	2.1
Recommended A.S.M.E. ratio	2.0	2.0	2.0	3.0	2.0

tion. No embrittlement has ever been experienced on waters meeting this code recommendation.

Table 3 gives the analyses of seven waters taken from the boilers from plants which have encountered embrittlement, and illustrates to what extent the hydroxide is formed.

Table 4 shows the analyses of waters taken from boilers which have operated on zeolite-treated waters and natural sodium waters followed by treatment to meet the sulphate-carbonate ratio. No embrittlement has ever been encountered in plants having waters like these in the boilers.

LABORATORY INVESTIGATION

The fact that the cracks were intercrystalline suggested a means of attack in the laboratory. The occurrence of intercrystalline cracking in boiler plate had never been reported under conditions which simulated boiler operation. A few isolated instances where selective corrosion had attacked the grain boundaries of steel had been reported, but the conditions were such as could not be encountered in operation. Boiler plate subjected to high stresses, impact tests, fatigue tests, corrosion fatigue, etc., are almost invariably transcrystalline and follow the line of maximum stress. These cracks may pass along one or two grain boundaries, but in general are transcrystalline.

The embrittled boiler plates are in general cracked intercrystalline, and it is the exception when the cracks cut across a grain. This has been used as a means of detecting embrittlement cracks. Since this distinct difference could be found between normal failures and embrittlement failures, attempts were made early in the investigation to reproduce this type of cracking at will under known test conditions. The attempts met with success and a tool was immediately placed at the disposal of the investigation to study the conditions of its occurrence and methods to stop it.

A brief summary of the results obtained from the laboratory tests conducted toward the explanation of this intercrystalline cracking is given below.

a Two conditions must be present simultaneously to cause embrittlement of mild steel in the laboratory test containers: first, the actual stress must be above the region of the yield point of the metal; and second, the concentration of solution must be above 75 grams per liter (about 4000 grains per gallon.)

b Solutions of salts occurring in boiler waters other than sodium hydroxide did not effect the stressed metal.

c Pure iron cracked as well as regular boiler plate.

d Cold work or heat treatment did not accelerate nor retard embrittlement cracking.

e Steel subjected to a high intensity of load for five years failed to crack; but the same steel under the same load cracked in less than three days when brought in contact with caustic solution.

f Increased steam pressure accelerates the cracking.

INHIBITING OF EMBRITTLEMENT

When the attention of the earlier investigators was first called to the fact that sodium hydroxide might be a contributing factor in the embrittling of boilers, attempts were made to stop the formation of the hydroxide in the boiler. The addition of organic matter was tried with no marked success, since it did not retard the decomposition of the carbonate to any extent. Early in 1914 attempts were made at the University of Illinois power plant to lower the sodium carbonate content in the feedwater by adding magnesium sulphate. This formed sodium sulphate and decreased the sodium carbonate content. Later this was changed to a sulphuric acid treatment. The regular lime treatment was made, and then sufficient sulphuric acid added to neutralize about two-thirds of the sodium carbonate in the water. Before adopting this system of treatment difficulty had been experienced on all boilers, but since adding this treatment no further difficulty of this nature has been encountered. A recent thorough examination of these boilers involving removing of rivets, and a thorough examination of the rivet holes showed that after ten years' operation on this treated water the boilers were free from any indications of embrittlement. Within recent years the tendency toward keeping a definite amount of sodium sulphate in all boilers using sodium carbonate waters has become popular with large-power-plant operators, so that at present over twenty plants are using this means to inhibit embrittlement. The method of increase of sulphate is accomplished by various means, some using acid while others use aluminum sulphate, iron sulphate, etc. Some plants which encountered embrittlement have changed to other sources of supply free from carbonate, with the elimination of the difficulty.

A local power plant operating on the same type of water supply as that used at the University of Illinois recently encountered serious difficulty in the form of embrittled drums. This power plant operated the boilers at about the same pressure as the University boilers and with the same make-up. The only apparent difference was that the University water was treated to increase the sulphate, while the other plant's supply was not. After eight years these boilers were badly embrittled, while the University boilers operating on the sulphate-treated water are still free from embrittlement.

The use of sulphate treatment is very limited, and since the occurrence of embrittlement is apparently on the increase, other methods of stopping it have been diligently sought. The use of a sulphate ratio on waters low in calcium and magnesium is possible, but when these salts are present it becomes practically impossible to keep the recommended ratios at the higher pressures. Furthermore the use of acid is only to be recommended when the direct supervision of a man conversant with the use of chemicals is available. An overdose of this medicine may result in more trouble than the original disease, consequently the operators and men responsible for large power units hesitate to use acid under average conditions of operation.

When evaporators are used on alkaline water it becomes difficult to get a water free from sodium carbonate. Table 5 gives the analyses of evaporated water from a few of such waters. The acid treatment of these waters is impossible. The addition of sodium sulphate defeats the purposes of evaporation,

TABLE 5 ANALYSES OF WATER FROM EVAPORATORS USING SODIUM CARBONATE WATER SUPPLY

	—Grains per U. S. Gal.—	
Calcium carbonate	0.21	trace
Magnesium carbonate	0.00	trace
Sodium carbonate	0.70	0.92
Sodium sulphate	0.54	0.78
Sodium chloride	0.34	0.68
Iron and aluminum oxide	0.00	trace
Silica	0.12	0.25

TABLE 6 INHIBITING EFFECT OF SODIUM PHOSPHATE ON EMBRITTLEMENT OF BOILER PLATE

(Stress on specimen, 45,000 lb. per sq. in.; steam pressure, 500 lb.)

Solution, grams NaOH per liter	Sodium phosphate ($Na_3PO_4.10H_2O$) grams per liter	Time of cracking	Length of time tested, no cracking
295	0	24 hours	.....
280	2	20 hours	.....
280	5	.....	17 days
280	0	20 hours	.....
280	10	.....	13 days
280	3	.....	13 days
280	5	.....	13 days
280	3	.....	15 days

TABLE 7 INHIBITING EFFECT OF TANNATE ON EMBRITTLEMENT OF BOILER PLATE

(Stress on specimen, 45,000 lb. per sq. in.; steam pressure, 500 lb.)

Solution, grams NaOH per liter	Tannate, grams per liter	Time of cracking	Length of time tested, No cracking
280	0	20 hours	.....
270	50	.....	10 days
275	5	20 hours	.....
275	15	.....	30 days
275	10	.....	30 days

consequently a new inhibitant is sought for this type of water.

The inhibitant must be non-corrosive, stop embrittlement in relatively small amounts, cause no trouble through overtreatment, require but a small amount of chemical control, and be inexpensive. Work has been conducted with good success toward the finding of inhibitants to meet these conditions.

The actual ratios of salts for the prevention of embrittlement have not been determined to the point where minimum limits can be set. The results indicate that for normal pressures the A.S.M.E. recommendations are safe and should be adhered to.

Methods of treatment for various types of waters and conditions of boiler operation are being investigated by the authors, having special reference to the development of further inhibitive conditions or reagents with the prospect of avoiding some of the present difficulties attending the maintenance of the sulphate ratio, and also greatly simplifying the procedure for the prevention of this very serious menace.

Reference has already been made to the possibility of the importance of the electrolytic potential in controlling embrittlement. The use of sodium dichromate as an inhibitive agent was suggested in Bulletin 94 of the Engineering Experiment Station of the University of Illinois, and its possible action attributed to its influence on the electropotential of the steel to caustic solutions. With this idea foremost, a list has been prepared of various chemicals which might be used in boiler waters to bring about this effect.

Tests have been conducted on a few of these salts, and the results obtained have been very encouraging. The addition of these salts to the regular caustic solutions used brought about the results given in Tables 6 and 7.

The data presented in these tables are entered in the same order in which the tests were conducted. These results indicate that comparatively small amounts of these inhibitive salts will retard the embrittling action of sodium hydroxide. Thus, as low as 3 grams per liter of sodium phosphate ($Na_3PO_4.12H_2O$) prevented embrittlement in the presence of approximately 300 grams per liter of sodium hydroxide at a steam pressure of 500 lb. When sodium sulphate was used at this pressure it was necessary to have five times as much sodium sulphate as sodium hydroxide. The phosphate appears to be effective as an inhibitant and requires only one part of sodium phosphate to 100 parts of sodium hydroxide—less than $^1/_{500}$ as much as the sodium sulphate. Similar figures can be shown for the use of tannate. Tests are being conducted with other salts as possible inhibiting agents.

The possibility of the use of these new inhibitants is at once evident, but their application in boiler-feedwater treatment should not be tried until more laboratory work is in evidence and more data can be collected from plant operation. It should be realized that these figures represent data collected from the accelerated laboratory tests and are not directly applicable to operating conditions.

CAUSES OF EMBRITTLEMENT IN STEAM BOILERS

The results that have been obtained from both embrittled boilers and laboratory investigation can be briefly summarized as follows:

a Material has not been found to be at fault.
b Design or workmanship of boiler is not primary cause.
c Operation of boiler is not to blame.
d Alkaline condition in boiler with low sulphate content is common to all embrittled boilers.
e Sodium hydroxide is the only material encountered in the boiler which embrittles stressed steel.
1 Concentration to produce embrittlement is higher than encountered in main body of boilers.
f Increased sulphate has been effective both in laboratory and plant in stopping this trouble.
g New inhibiting agents have been developed.

All the data from the plants show that boilers crack in intercrystalline manner only when used on alkaline waters low in sulphates. This cracking has been stopped by increasing the sulphate or lowering the sodium hydroxide content. Plants free from it for years have suddenly encountered trouble when an alkaline water has been used. The laboratory results show that sodium hydroxide is the only chemical in the water which would cause this kind of cracking on stressed steel. A correlation of these facts shows conclusively that the offending agent has been the sodium hydroxide in the boiler. The only questions which arise are: How does the caustic act in the seams, and how does the stress exist in a magnitude sufficient to cause the caustic attack to start? It can be shown that these boilers with a factor of safety of around 5 have a calculated theoretical stress of 11,000 to 12,000 lb. per sq. in. between the rivet holes. This is calculated and assumes that the rivet holes are theoretically in line, stresses evenly applied, and all metal perfectly equal in physical properties. Allowing for the concentration of stress due to the discontinuity of the metal, the actual stress at the rivet hole becomes nearly three times the average stress in the plate or about 33,000 lb. per sq. in., approximately the yield point of the boiler plate. When there is added to this the concentration of stresses brought about due to the fact that the holes cannot be absolutely in line, the riveting pressure causes slight deforming, the calking causes excess stresses, etc., there can be little doubt that a local stress of a magnitude about that of the yield point exists. In some boilers a factor as low as $3^1/_2$ has been used, yet the high resulting stresses alone have not produced embrittlement. The factors used have resulted from experience gained through years of boiler design and operation and use of boiler plate. Many examples of evidence of stresses of a magnitude equal to the yield point of boiler plate in boilers are available.

The laboratory results show that the presence of a concentration of about 4000 grams of sodium hydroxide will embrittle a piece of stressed steel. It has also been demonstrated that if the

solution be allowed to penetrate between two plates as a thin film, the time of cracking and likewise the concentration necessary is reduced. The fact that cracking occurs in a smaller space of time when the solution penetrates between two plates may be explainable in two manners. First, due to lack of circulation and reaction with the steel the concentration increases locally. Analyses made of the coat on the iron after contact with the sodium hydroxide show it to be Fe_3O_4. The reaction to produce this is undoubtedly

$$3Fe + NaOH + 4H_2O \longrightarrow Fe_3O_4 + NaOH + 4H_2$$

The NaOH merely acts as an accelerating agent by increasing the electromotive force of the solution to the steel. The only materials actually used in the reaction are iron and water. As the water is used it concentrates the caustic in the thin film of solution and increases the reaction. The second explanation is that a thin film of liquid in immediate contact with two plates may have a higher activity than a large amount of solution surrounding a piece of steel. No statement can be made relative to the actual concentration in the seam. Bauman[5] has shown that concentration can take place in a theoretically constructed seam in which there was a possibility for diffusion but not outside leak. If the diffusion possibility were reduced so as to simulate actual boiler operation, no doubt exists as to the possibility of obtaining much higher concentrations than those obtained by Bauman. Berl[6] has reported the results of research on the possibility of concentration in seams and the effect of caustic soda solutions on iron at high pressures. He found that sodium hydroxide solutions of about 200 grams per liter readily attacked iron with the evolution of hydrogen at pressures around 100 atmospheres. He reported but little effect of solutions of caustic of the normally concentration encountered in steam boilers on steel. From these results he concluded that the caustic solutions would have to be concentrated before attacking the steel in boilers, and ran experiments to prove whether or not the solutions would concentrate in the small crevices in the seams. He made capillary tubes, sealed these at one end, and connected the other ends to larger tubes. Solutions of about one gram per liter of different salts were put into the tubes. The volume of solution in the capillary part was extremely small in comparison with that in the larger tubes. The capillary was heated, thus vaporizing the liquid adhering to the walls of capillary, which on vaporizing left a small amount of the salts on the walls. On cooling, the liquid from the larger tube forced its way into the capillary. After repeating the heating and cooling a great many times the solution in the capillary slowly concentrated while the solution in contact with it but in the larger tube remained practically the same as at the start. By means of this procedure Berl caused the solutions to reach their saturation point in the capillary with the subsequent precipitation of the salt from solution without concentrating the solution in the larger tube. He then went on to show that the seams in steam boilers have numerous capillary spaces in which the solutions could concentrate in this manner. The raising and lowering of the steam pressure, the heating and cooling of the boiler, etc. all tend to favor the slow concentration in these capillary spaces. In these experiments diffusion was reduced to a minimum. Furthermore, if the solution reacted with the steel like caustic solutions do, the concentration due to chemical reaction would cause an increase when full circulation was lacking. If a small leak should exist the possibility of concentration would increase. All these facts indicate that an increase of concentration within the seam can take place to a sufficient degree to cause embrittlement.

The Effect of Running In on Journal-Bearing Performance

A FEATURE recognized by the operators of machines containing journal bearings is that a certain amount of "limbering up" or "running in" is necessary before this type of bearing behaves in a normal manner. A paper read by S. A. McKee[1] at the 1927 Annual Meeting of the A.S.M.E. and published in MECHANICAL ENGINEERING, last December, p. 1335, described an investigation at the Bureau of Standards, the object of which was to evaluate this effect of running in upon the performance of babbitted, full-journal bearings.

A specially designed journal-bearing friction machine provided a method of measuring the frictional loss in a journal bearing when operating under different conditions of load on the bearing, speed of the journal, and viscosity of the lubricant. By correlating these factors in a suitable manner a measure of the effect of progressive amounts of running in on bearing performance was obtained.

The results indicated that running in causes a marked reduction in the frictional loss of a bearing under very severe operating conditions.

In conclusion the author pointed out the effect of running in upon the factor of safety of a bearing, and indicated the possibility of increasing the efficiency of high-speed journal bearings by a hypothetical example of a steam-turbine bearing.

Mr. McKee's paper drew forth several illuminating comments from men peculiarly fitted to discuss its subject-matter. These immediately follow.

H. A. S. HOWARTH.[2] The author has presented valuable data which should assist greatly in the formulation of safe rules for the factor of safety of journal bearings. It seems that he might with profit have added to his f-(ZN/P) charts (Figs. 5, 7, and 8) the theoretical curves of relation between those terms. One could then see how nearly the test values approached the best that could be expected.

The author has pointed out that on these charts test data on bearings with different clearances produce curves of different slopes. It is therefore desirable to design a chart on which test data on bearings of all clearances may be compared with a single theoretical curve. If at the same time some idea of the percentage of eccentricity and the closeness of approach of the surfaces may be visualized—again by reference to a single curve—a clearer idea of bearing conditions can be had and a safer estimate can be made of the value of the test results under consideration.

[5] Bauman, "Zur Sicherheit des Dampfkesselbetriebes," Julius Springer, Berlin, 1927.

[6] Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, Heft, 295, 1927.

[1] Assistant Mechanical Engineer, Bureau of Standards, Washington, D. C.

[2] General Manager and Chief Engineer, Kingsbury Machine Works, Frankford, Philadelphia, Pa. Mem. A.S.M.E.

From the mathematical analysis of full bearings, which would lead to the adoption of the f-(ZN/P) chart, there can be obtained, by going a step further, a combination chart of similar nature that will make possible the desired analysis of test results. Such a chart, using Harrison's symbols,[3] would have for its base scale $\frac{\mu N}{w}\left(\frac{a}{\eta}\right)^2$, for its right-hand vertical scale the clearance percentage c, and for its left-hand vertical scale the friction-coefficient term $\lambda\left(\frac{a}{\eta}\right)$. These symbols have been chosen to agree with those of Reynolds and Harrison, and to avoid confusion that might arise if the letter c were used with two different meanings. At the top of the chart the corresponding $\frac{ZN}{P}\left(\frac{a}{\eta}\right)^2$ scale may be placed, using $\frac{a}{\eta}$ instead of the author's $\frac{D}{C}$ to avoid confusion.

Three figures are offered using the scales above described. Fig. 1 covers the range of $\frac{\mu N}{w}\left(\frac{a}{\eta}\right)^2$ from 0 to 10 and $\lambda\left(\frac{a}{\eta}\right)$ from 0 to 6, Fig. 2 about double this range, and Fig. 3 ten times the range of Fig. 1. The theoretical curve J of journal friction is drawn on each chart.

The critical portions of the curves in the author's Fig. 8 are plotted here in Fig. 2. The four low points are marked D, E, F, and G, respectively. By running in bearing set No. 1 point F is lowered to G, while by running in set No. 2 point D is lowered to E. Points D and E are both well above the theoretical curve J, whereas point F is close to it and point G below it.

Before discussing the probable reason why F and G are so close to the curve J, it is profitable to examine the eccentricities and minimum film thicknesses given in Table 1.

TABLE 1

For point	c	Min. film thickness	$\lambda\frac{a}{\eta}$	$\frac{ZN}{P}\left(\frac{a}{\eta}\right)^2$	$\frac{a}{\eta}$	$\frac{\mu N}{w}\left(\frac{a}{\eta}\right)^2$
D	0.03	0.00027	12.36	136.3×10^6	2250	19.75
E	0.34	0.00018	3.82	22.7×10^6	2250	3.29
F	0.79	0.00032	1.17	7.075×10^6	450	1.025
G	0.98	0.00003	0.72	2.26×10^6	450	0.328

The journal in bearing set No. 2, because of its small clearance $\eta/a = {}^1/_{2250}$, ran nearly concentric ($c = 0.03$) for point D, and the minimum film thickness was approximately 0.00027 in. After running in, however, the low point had shifted to E, having a greater eccentricity ($c = 0.34$) and a thinner film (0.00018 in.)

The journal in bearing set No. 1, because of its large clearance $\eta/a = {}^1/_{450}$, ran quite eccentric ($c = 0.79$) for point F, and the minimum film thickness was about 0.00032 in. After running it in the low point shifted to G, whose eccentricity was very high ($c = 0.98$) and whose film was very thin (0.00003 in.)

The author stated that bearing set No. 1 had been used in previous tests with an abrasive in the oil. This might result in some preliminary running in that would account for the high eccentricity and very thin film found for point G.

With regard to the closeness of F and G to curve J, several explanations are offered: (*a*) The oil film may have been far from perfect and the bearing may have acted more nearly like a half than a full bearing. (*b* The wearing in of the two surfaces may have resulted in the equivalent of a smaller clearance ratio in the region where most of the friction took place. This is suggested by the author in discussing the slight convexity upward of the curves of his test data just to the right of his curve reversals at minimum friction: (*c*) Mr. Kingsbury has suggested that the film temperatures measured by the author are probably too low, and that the actual viscosity within the film is much lower than he found. Hence if the measured friction was plotted against a lower viscosity than estimated by the author, the point would have a shorter abscissa, thereby approaching less closely to the theoretical curve J, except in cases of the lower points on curves F and G. (*d*) Side leakage would disturb the pressure distribution within the film, and would cause the point of nearest approach to lie nearer the line of the applied load for a bearing with large clearance than for one with small clearance. Hence the shaft deflection would have a greater influence on the running in of a bearing with large clearance than in one with small clearance.

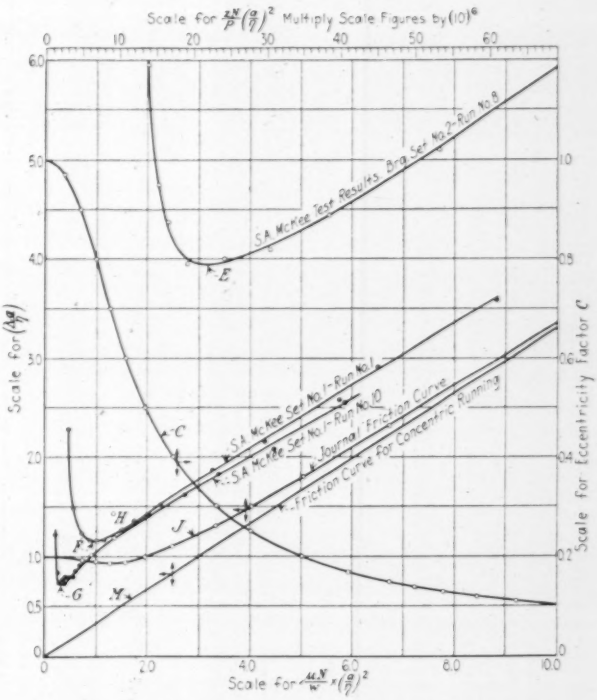


FIG. 1 TEST REFERENCE CURVES FOR FULL BEARINGS

[Curves C, J, and M are theoretical curves based on constant viscosity and no side leakage. Curves E, F, and G are plots of the author's (S. A. McKee's) test data.]

It is probably too early to adopt a factor-of-safety rule such as the author suggests. He dealt with a very small bearing. We do not know what relative accuracy is probable in the making of a 1-in. diameter and a 10- or a 20-in.

Bearing-shell design and mounting have a large influence upon the results to be expected from running in.

There are many bearings that start under full load and with adequate lubrication. Their friction coefficients at starting would vary from 0.15 to 0.20, or about 100 times the minimum coefficients that the author obtains. As such journals gather speed their friction coefficients *fall off* rapidly to about one-hundredth of the starting value. From that point on the coefficient *goes up* with the speed. The fact that a vast number of bearings start and stop frequently without injury proves that they can pass through the regions of "unstable" and "stable" lubrication with impunity.

[3] μ = coefficient of viscosity, inches, pounds, seconds.
N = r.p.m.
w = pressure per square inch of projected area.
a = journal radius.
η = radial clearance.
$a+\eta$ = radius of bore of bearing.
λ = coefficient of journal friction.
c = eccentricity factor.
$c\eta$ = eccentricity of journal in bearing.

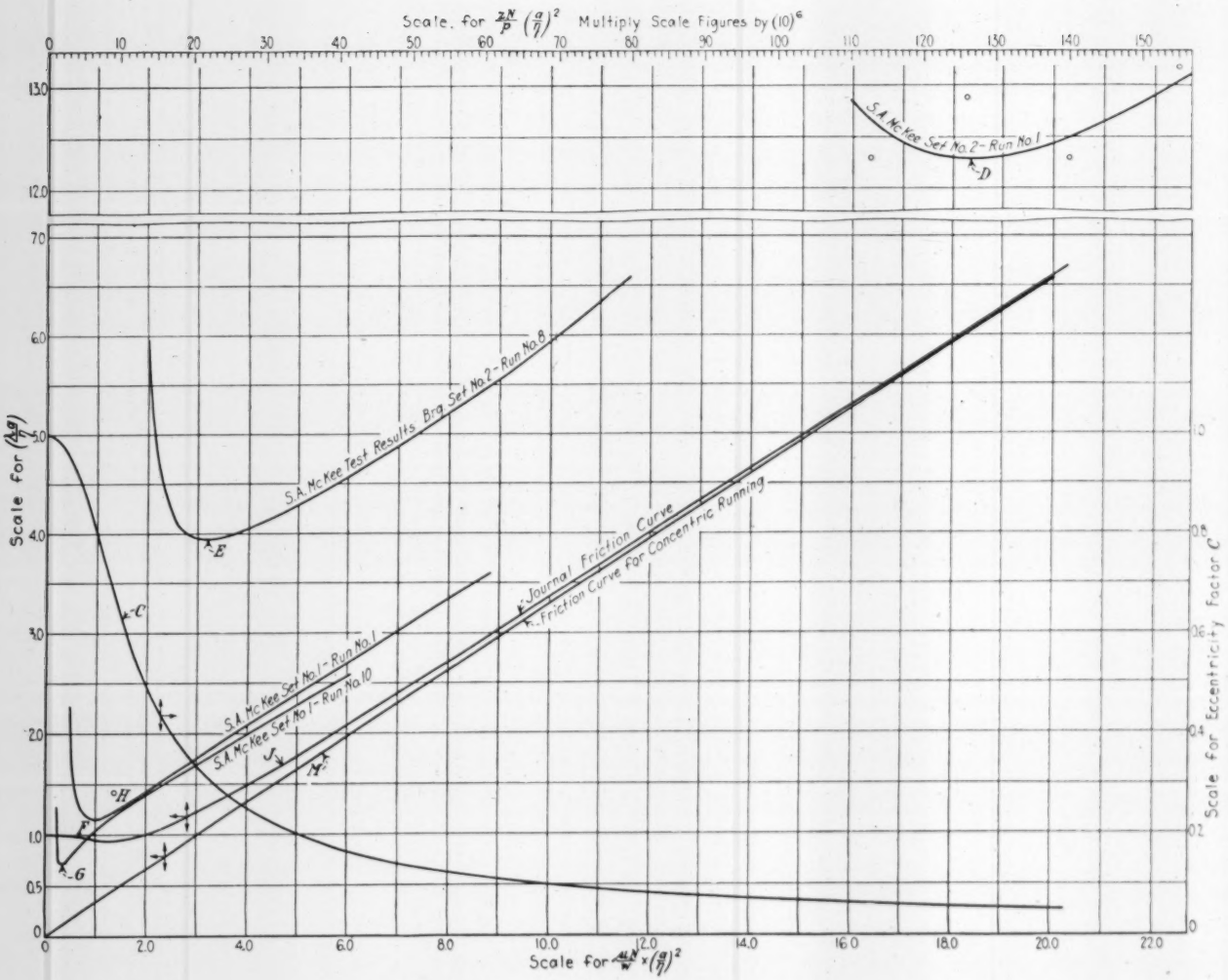

Scale for $\frac{zN}{p}\left(\frac{a}{\eta}\right)^2$ Multiply Scale Figures by $(10)^6$
S.A. McKee Test Results Brg. Set No. 2 - Run No. 8
S.A. McKee Set No. 2 - Run No. 1
S.A. McKee Set No. 1 - Run No. 1
S.A. McKee Set No. 1 - Run No. 10
Journal Friction Curve
Friction Curve for Concentric Running
Scale for $\left(\frac{fg}{\eta}\right)$
Scale for Eccentricity Factor C
Scale for $\frac{\mu N}{w}\times\left(\frac{a}{\eta}\right)^2$

FIG. 2 TEST REFERENCE CURVES FOR FULL BEARINGS

[Curves *C*, *J*, and *M* are theoretical curves based on constant viscosity and no side leakage. Curves *D*, *E*, *F*, and *G* are plots of the author's (S. A. McKee's) test data.]

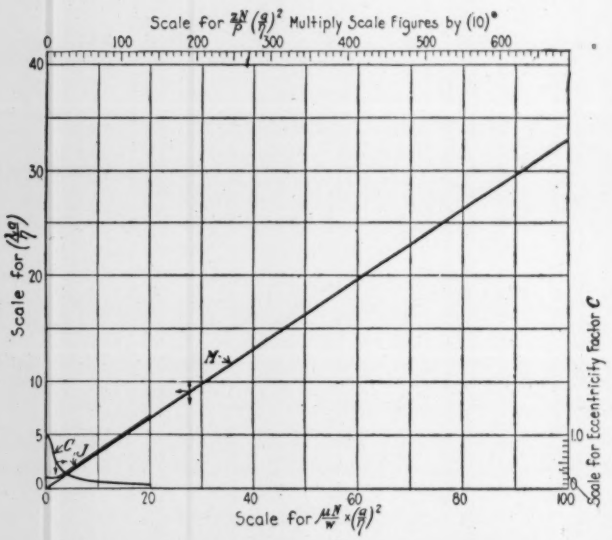

Scale for $\frac{zN}{p}\left(\frac{a}{\eta}\right)^2$ Multiply Scale Figures by $(10)^6$
Scale for $\left(\frac{fg}{\eta}\right)$
Scale for Eccentricity Factor C
Scale for $\frac{\mu N}{w}\times\left(\frac{a}{\eta}\right)^2$

FIG. 3 TEST REFERENCE CURVES FOR FULL BEARINGS

(Curves *C*, *J*, and *M* are theoretical curves based on constant viscosity and no side leakage.)

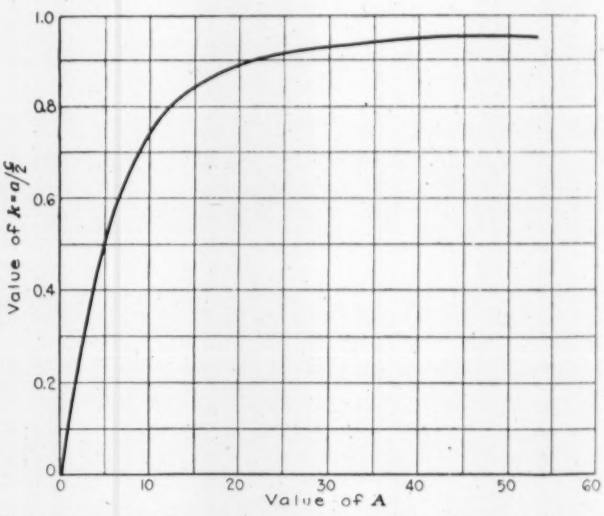


FIG. 4 RELATIVE ECCENTRICITY OF A JOURNAL IN ITS BEARING AS A FUNCTION OF THE CHARACTERISTIC NUMBER

$$A = 197.6\left(1000\,\frac{c}{D}\right)^3 \times \frac{1}{ZN/P}$$

In the region of stable lubrication, oil passing between the bearing surfaces produces fluid friction, the heat from which in a full bearing can be dissipated throughout the circumference, even though at low speeds it is nearly all produced at the region of nearest approach of the surfaces. As the speed slows down through the range in which metallic rubbing is increasing, the amount of oil passing through the region of close approach decreases. It is here that we may look for trouble when the area of contact is so small that the heat cannot be conducted away fast enough to prevent the overheating of the bearing metal.

We do not know the generalized speed (ZN/P) at which this metallic contact would become dangerous. The oil film would be more persistent in a bearing with small clearance than in one with large clearance. Hence we should expect the one with small clearance to run without harm at a lower speed than the one with large clearance. This would justify the use of the $\frac{ZN}{P}\left(\frac{a}{\eta}\right)^2$ scale, and would suggest that the possibilities of improvement by running in bearing set No. 2 in the author's tests were only begun. This appears obvious from the writer's Fig. 2, but is not evident from Fig. 8 of the paper.

If running in changes the clearance provided in the test bearing, in the region of closest approach, where most of the friction is produced, the measured friction would be the only known experimental factor in the ordinates of our curves. The diameter of the journal may be assumed not to change. The shape of the bearing surface undoubtedly does change.

Of the abscissa factors we know the load, the speed, and the journal diameter. We do not know the bearing-surface shape and size or the viscosity. Hence for the study of plots of test results on the $\mu\left(\frac{a}{\eta}\right), \frac{ZN}{P}\left(\frac{a}{\eta}\right)^2$ diagram, we must make certain assumptions with regard to our unknowns and see whether the other factors are thereby shown to act in a normal manner.

We may assume the viscosity to be known and then discuss the probable clearance changes by running in. Curves for bearing set No. 1, runs 1 and 10, are convenient for study, containing as they do low points F and G, respectively. Only the known initial clearance ratios were used in plotting test data that gave the curves on which they lie.

If data for low point F were obtained before any running in was done, and if we assume that the viscosity was estimated correctly, point F would be properly located on the chart. After running in for some time similar data were taken. Assuming again that the viscosity is estimated correctly, and then assuming what we believe to be incorrect—that the effective clearance ratio is not changed by running in—we obtain the coordinates of low point G.

If, however, the effective clearance is changed so as to be only *half* what it was before running in, and if the true clearance were used in plotting the low point, we should have to locate it at H, whose ordinate is *twice* and whose abscissa is *four times* that of G.

It will be noted that H lies above F. Hence our assumption as to change in clearance was apparently excessive. If we had assumed that the effective clearance decreased to about two-thirds its original value, we should have had to plot our point almost exactly at F instead of at G or H. It would perhaps be too much to expect that, if we knew all the clearance ratios, the curves containing F and G would be superimposed.

The viscosity within the film is not definitely known. Even if the temperatures of the bearing and shaft metal were accurately known, there is no assurance that the average viscosity of the oil film would correspond. In the author's tests the shaft was cooled, whereas the bearing-metal temperature was measured. The heat flow was toward the shaft. Hence the viscosity of the oil film might be greater than estimated. If there is an appreciable temperature drop at the bearing surfaces as heat flows from the oil to them, the film viscosity might be less than estimated.

A greater viscosity would produce greater friction, and we should expect the abscissas to be shorter when the viscosity correction is made. A lower viscosity would produce less friction and we should expect the abscissas to be longer when the viscosity correction is made.

In view of the above comments, it seems to the writer that test data for bearings with running clearance should be studied by reference to a chart that takes the theoretical influence of the clearance into account, as in the figures offered herewith. Similar charts can be prepared which will be suitable for partial bearings. By means of such charts the influence of side leakage can readily be studied. We can also more intelligently compare test results from different bearing designs, varying the length, diameter ratio, the metal distribution, shaft deflection, and the methods of oiling and cooling.

H. DAHLSTRAND.[4] This interesting paper shows the possibility of materially improving the efficiencies of bearings by running in the bearing, thereby smoothening the surfaces so that a higher pressure, a lower-viscosity oil, or both, may be used in the design, thus reducing friction losses.

That increased bearing pressure or the use of lower-viscosity oil reduces the friction losses has of course long been known, and has been taken advantage in the design of steam-turbine bearings. Extreme care must be used in making perfectly smooth surfaces by scraping or by employing specially designed tools for the machining. It is obvious, however, with the progress made in the design and with the extremely large turbine units now being built, that a greater knowledge of the lubrication problem will result in a more efficient and safer bearing design.

Whether the running in of steam-turbine bearings would result in reducing the losses without at the same time endangering the operation of the turbine, is questionable. It must be borne in mind that in order to guard against any trouble when starting up a large steam-turbine unit, it is necessary to heat up the various parts of the turbine gradually in order to avoid dangerous distortions in the various parts. For this reason it is necessary, particularly on large units, to run the steam turbine at a very low speed for a considerable length of time. During this time it is possible the unit will run at a speed of unstable lubrication and, consequently, a breaking down of the oil film may occur, thereby damaging the bearing.

Whether it will be practical to take advantage of the benefits derived from a proper running in of the bearing as proposed by the author is difficult to say. Undoubtedly it will be costly, as special equipment must be used in order to properly control the work.

Referring to the example of the possibility of saving power, as given in paragraph (*f*) of the paper, it is not clear how the curve f-(ZN/P) shown in Fig. 1 was arrived at. The assumption would be that with a constant C/D ratio and a constant ZN/P, the coefficient of friction will be constant. It would be interesting to know whether that is true for all types and sizes of bearings.

The author's tests show that the clearance between the journal and the bearing has a great influence on the friction losses. It is obvious, therefore, that this clearance, in order to obtain the most economical result, should have a certain value. This clearance will, of course, depend upon the viscosity of the oil, kind of oil, size of bearing, and probably the speed and methods of lubrication used for different types of bearings. It appears,

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therefore, if reliable data are to be developed covering all the factors influencing the bearing design, extensive research and experimental work are necessary.

There has been very little actual information published on bearings running at high speeds, such as those used in large turbo-generators. In this type of machinery we are using peripheral speeds up to 150 ft. a second or higher at pressures of about 150 lb. per sq. in., and naturally it would be interesting to know all the details in connection with the lubrication of such bearings in order to develop the best and most economical design. At the present time the steam-turbine designer can only base new designs on experience gained in the past, trusting that this experience will enable him to successfully meet the new problems.

G. B. KARELITZ.[5] The experiments described in the paper are very interesting. Apart from the importance of bringing out the effect of running in, some instructive conclusions may be drawn from the results given by the author.

Taking into consideration the small size of the bearings and their consequent comparative rigidity under the loads applied, the first of the two explanations of the results which are given by the author is more acceptable: namely, that certain high spots on the bearings come in contact with the journals and break the oil film. These imperfections wear off, and with gradual running in of the bearings fluid friction may be maintained at lower values of ZN/P.

On the basis of the calculations made by L. Guembel,[6] and taking the longitudinal efficiency[7] of a bearing equal to $^2/_3$, the position of a journal in the clearance may be found in the case of bearings such as used by the author as follows: a being the eccentric displacement of the shaft from the center of the bearing for given conditions of load, speed, and viscosity of the oil in the clearance, and $c/2$ being the radial clearance of the bearing, the relative eccentricity $k = a/(c/2)$ is a function of a characteristic number A, as shown in the accompanying Fig. 4. The number A may be found by using the formula

$$A = 197.6 \times \left(1000 \frac{c}{D}\right)^2 \Big/ \frac{ZN}{P}$$

the notation used being the same as that in the paper. The ratio c/D being known, the number ZN/P defines A, and the curve gives the value of k. The minimum thickness of the oil film is then $t_0 = (1 - k)\frac{c}{2}$. Using this curve, the minimum thickness of the oil film in the experimental bearings can be found (1) for the case when the friction line starts to deviate from a straight line, i.e., when rupture of the oil film by protruding imperfections just begins; and (2) for the point of minimum friction. The paper gives the corresponding values of ZN/P, from which the respective values of A, k, and t_0 can be found. This is done in Table 2.

It is interesting to note that the values of t_0 change by similar amounts from run No. 1 to run No. 8 for both sets of bearings, namely, 0.00011 in. for set 1 and 0.00012 in. for set 2.

The very small thickness of the oil film shown in the table is quite sufficient for hydraulic phenomena to manifest themselves, i.e., this film may be considered as a liquid in bulk, since the molecular dimension is of the order 10^{-7} cm. Anyway, Dr. T. E. Stanton[8] found in a bearing of phosphor-bronze on a steel journal of 1 in. diameter the values 0.000054 in. and 0.000046 in. for the minimun oil thickness.

TABLE 2

Bearing set No.	1	2
Relative clearance (c/D)	1/450	1/2250
$A \times \frac{ZN}{P} = 197.6 \times \left(1000 \frac{c}{D}\right)^2$	981	38.9
Radial clearance ($c/2$)	0.00135 in.	0.00028 in.
1—Value of ZN/P when the friction curve starts to deviate from a straight line during the first run	55	70
Value of A	17.9	0.56
Value of k	0.88	0.03
Value of $1 - k$	0.12	0.97
Value of $t_0 = (1 - k)\frac{c}{2}$	0.00017 in.	0.00027 in.
2—Value of ZN/P when the friction curve starts to deviate from a straight line during the run No. 8 (after 2500 ft-lb. of work spent in friction)	18	10
Value of A	55	3.9
Value of k	0.953	0.454
Value of $1 - k$	0.047	0.546
Value of t_0	0.000063 in.	0.00015 in.
3—Value of ZN/P at minimum friction during the first run	32.5	26
Value of A	30.2	1.49
Value of k	0.928	0.155
Value of $1 - k$	0.072	0.845
Value of t_0	0.000097 in.	0.00024 in.
4—Value of ZN/P at minimum friction after running in is given	6	3
Value of A	163	12.9
Value of k	0.98[a]	0.81
Value of $1 - k$	0.02	0.19
Value of t_0	0.00003 in.	0.00005 in.

[a] By graphic extrapolation on log paper.

On the other hand, direct measurements on a large industrial motor by V. Vieweg[9] showed the thickness of the oil film when rupture starts to be of the order of 0.01 mm. = 0.00040 in. These were lead-base babbitt bearings with a steel journal.

It seems that the basis used by the author for evaluation of the safety factor by the value of ZN/P at minimum friction is not correct. The thickness of the oil film in the bearing in comparison with a certain minimum allowable thickness would be a more practical scheme, and the corresponding conclusions in the paper may be questioned. Continuation of tests along the line followed by the author of the paper would be very desirable, and would probably yield interesting data on requirements in finish for bearing and journal rubbing surfaces.

A. E. FLOWERS.[10] Judging from the plotted results, the reduction of the friction coefficient or point of change from stable to unstable lubrication due to the addition of a small amount of fatty acid to the mineral-oil lubricant is exceedingly small. It would be desirable if the author would elaborate on this point, upon which adequate information is lacking.

While there might be a low value for this critical point with a well-run bearing, there might at the same time be some danger in applying it unless the bearing was run with a high-viscosity oil and then changed over to a lower-viscosity oil while running. Otherwise the starting conditions below full speed would require a different relation in order to have stable lubrication and safe operation, because at the lower speeds high viscosity is needed for the carrying of the oil. Possibly the change of temperature between starting and operating might be sufficient to provide that factor of safety, and possibly it might not, which leads to the rather startling suggestion that whenever it was important to save power, heavy oil would be used at the start, and light

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[6] "Friction and Lubrication in Machine Building" (Reibung und Schmierung im Maschinenbau), L. Guembel and E. Everling, Berlin, 1925. See also H. A. S. Howarth, "A Graphical Analysis of Journal-Bearing Lubrication," Trans. A.S.M.E., 1923–1925, and G. B. Karelitz, "Charts for Studying the Oil Film in Bearings," Trans. A.S.M.E., 1925.

[7] G. B. Karelitz, "Charts for Studying the Oil Film in Bearings," Trans. A.S.M.E., 1925.

[8] "Friction," by T. E. Stanton, Longmans, Green & Co., London, 1923, p. 102.

[9] V. Vieweg, "Optische Messgerate zur Bestimmung der Dicke der Oelschicht in Lagern." (Optical Methods of Measuring the Thickness of Oil Films in Bearings.) Wissenschaftliche Abhandlungen der Physikalische-Technische Reichsanstalt, vol. 6, no. 2.

[10] Engineer in Charge of Development, De Laval Separator Co. Poughkeepsie, N. Y. Mem. A.S.M.E.

oil when the shaft was up to speed. The author states that in the two different runs on the first bearing he had an operating temperature of 80 deg. fahr. with straight mineral oil and 77 deg. when fatty acid was present. It would be of interest to learn whether this was due to a change of room temperature, or whether the room temperature was constant and there was a lower temperature rise with the mixed oil.

A. C. BECKER.[11] If the bearings used by the author were not entirely filled with oil, it would be natural to assume that the minimum point on the curve might be below the theoretical value. Several years ago the writer presented a paper before the American Chemical Society in which he described a method of determining film thicknesses by measuring the electrical capacity of the oil-film condenser. Certain oils have film thicknesses as little as 0.0006 in. In all cases, regardless of how thick the minimum film is that can be measured, the indications are that the film breaks down very suddenly, and the breaking-down point depends on the oil used as well as on the bearing metal. A given oil in one bearing combination may not give a film thinner than, say, 0.0002 in., while in another combination it may be as low as 0.00006 in.

AUTHOR'S CLOSURE

Mr. Howarth's method of plotting such that the theoretical curves for bearings of all clearances free from end leakages are identical, is a valuable contribution to the study of journal-bearing performance.

One point of difference between it and the f-(ZN/P) relation, however, is that Mr. Howarth's chart is based upon theoretical equations which do not take into account the effects of end leakage, while by dimensional analysis the f-(ZN/P) relation has been shown to hold for bearings that have end leakage.

It was realized that there was a possibility of a difference between the effective and observed temperatures of the oil film, as suggested by Mr. Kingsbury, consequently the necessary precautions were taken to keep this effect small. The cooling water was at room temperature. By using light loads and low speeds the frictional power was kept low, the value per bearing for points D, E, F, and G being 0.00005, 0.00011, 0.00014, and 0.00010 hp., respectively. The maximum value per bearing at the high values of ZN/P was 0.017 hp., the temperature difference between bearings and room at this point being 4 deg. cent.

The runs were made in such a manner that a check can be obtained on the accuracy of the temperature determinations. In obtaining the data for most of the curves the load was increased at some point during the run, and usually the speed was increased sufficiently so that the points obtained with the high load overlapped those with the low load. Generally the load was doubled in these cases, and in order to obtain a higher value of ZN/P the speed had to be more than doubled. Thus the frictional power and heating effect would be more than four times as great as when running with the light load. If the observed temperature differed appreciably from the effective temperature, it would be indicated on the f-(ZN/P) curves where the points with the different loads overlap. In all cases it appears that the effect is negligible, the deviations from the curve between points having the same load being nearly as large as—and in some cases larger than—the deviations between points with different loads.

Tests are being continued on bearings of this type having various lengths and clearances and which have not been run in. When these tests have been completed it is probable that the remaining questions raised by Mr. Howarth can be answered more completely than would be possible at present.

[11] Standard Oil Development Co., Elizabeth, N. J.

Mr. Dahlstrand has pointed out one very important phase of the problem of journal-bearing lubrication, namely, whether the f-(ZN/P) curve for a small bearing of a given length and clearance applies to a larger-diameter bearing of the same relative length and clearance. Theoretically, it should not, unless the relative roughness of the surfaces, deflection due to load, and distortion due to uneven heating are either negligible or are geometrically similar in the two bearings. Therefore it is considered very desirable to extend these experiments to larger bearings.

Referring to the question by Mr. Karelitz as to the relative merits of using the point of minimum friction or some arbitrarily chosen theoretical film thickness as a basis for evaluating the factor of safety, it would seem that the use of the minimum point ought to be the more direct of the two, provided sufficient experimental data are obtained to cover the different types and sizes of journal bearings used in practice. Of course, until these data have been obtained it will be necessary to resort to some such method as Mr. Karelitz suggests. It should be pointed out, however, that the values of the film thickness given both by Mr. Karelitz and Mr. Howarth are theoretical values, and that at the present time there is no experimental evidence to indicate that these values are the same as would be found in an actual bearing. In fact, it is to be expected that they might be widely different at low values of ZN/P, for the theoretical values are based on the assumption of perfectly true surfaces, and these are never obtained in practice. For example, from Mr. Karelitz's Table 2, the theoretical minimum film thickness at the point of minimum friction for the first run with the second set of bearings is 0.00024 in., and for the last run 0.00005 in. Using these theoretical film thicknesses as a basis, it would appear that the factor of safety at the minimum point in the first run was far greater than that at the minimum point in the last run, yet experimentally the factor of safety was the same in both cases, for a slightly lower speed or viscosity, or a greater load would tend to throw the respective operating conditions of both into the region of unstable lubrication.

Referring to Dr. Flowers' question regarding the effect of fatty oils upon the point of minimum friction, Barnard, Myers, and Forrest,[12] using a bronze bearing 1 in. in diameter and 2 in. long with a steel journal found that the so-called "high-oiliness" oils had a tendency to lower the value of ZN/P at the point of minimum friction to a slight extent. The author found this same effect when using a $3^3/_8$-in.-diameter babbitt-lined bearing that was well run in to study the effect of the addition of kerosene to lubricating oil.[13] The slight difference noted by Dr. Flowers between the average operating temperatures when using the straight mineral oil and when using the oil with fatty acid was due to a corresponding change in room temperature.

AMONG the interesting properties of helium that may suggest new uses are complete chemical inertness, a specific gravity of less than one-seventh that of air, thermal conductivity over six times as great as air, high specific heat, the lowest boiling point known, namely, —267.8 deg. cent., and the ability to conduct sound nearly two and a half times as rapidly as air. The gas was first discovered in the sun through the spectroscopic observation, by Janssen and Lockyer, of the solar eclipse of August 18, 1868. In 1894, Rayleigh and Ramsay discovered argon in the atmosphere, and during the following year Ramsay, continuing his search for argon, found helium in the mineral cleveite.—*The Engineer*, May 25, 1928, page 573.

[12] D. P. Barnard, 4th, H. M. Myers and H. P. Forrest, "The Effect of Oiliness on the Behavior of Journal Bearings," *Ind. & Eng. Chem.*, vol. 16 (1924), pp. 347–350.

[13] S. A. McKee, "Effect of Kerosene on Oiliness of Lubricating Oils," *Jl. S.A.E.*, vol. 19 (1926), pp. 356–360.

Control of Costs of Building Tools

An Outline of the Plan Employed by the Hawthorne Works of the Western Electric Company In Accelerating the Output of Work Involved in the Manufacture and Repair of Tools

By G. A. PENNOCK,[1] CHICAGO, ILL.

IT IS THE purpose of the present paper to discuss some of the means of speeding up output on a class of work which is in a sense non-repetitive, and therefore difficult to measure. Specifically, there will be outlined briefly the problem at the Hawthorne Works of the Western Electric Company relative to the manufacture and repair of tools and to explain what is being done there to get better measures of performance on this class of work, which is usually carried out on the straight-day-work plan.

The Western Electric Company manufactures approximately 110,000 different parts, which are assembled into some 13,000 separate pieces of apparatus. The majority of these parts are used in electrical apparatus of delicate design and operation, and must therefore be manufactured to a comparatively high degree of accuracy. To produce some of its large annual requirements of parts, which in many cases run into the millions, oftentimes requires a number of identical tools. The tools, therefore, must be held to very close limits so that the parts produced will be absolutely interchangeable. A very large variety of tools, such as punch-press tools of all descriptions, rubber and bakelite molding dies, fixtures of every conceivable design, and thousands of small tools, such as button dies, taps, circular cut-off and form tools, etc., are required for the various operations necessary in the production of so great a number of parts. Consequently the company has approximately $12,000,000 invested in tools and $1,000,000 in tool-room equipment. In round numbers about 4500 major tools are manufactured annually, costing approximately $850,000, and small tools costing $485,000. In addition to these new tools, about 30,000 tools are repaired annually at a cost of $540,000; that is to say, each year the tool room builds or repairs tools of all types at an expenditure of approximately $1,875,000. These tools range in cost from a $12,000-punch and die to an engraving cutter costing less than 2 cents. Approximately 600 men are employed in the tool room in addition to 45 tool-making apprentices. Over 250 machines of all types are used in the manufacture of the tools, and 35,000 sq. ft. of floor space is devoted to this purpose.

Tool-Room Groups

The tool room is divided into the following main groups: the milling-machine section, the lathe section, the grinding section, and the bench-work section. There is also a department forming a part of the tool-manufacturing organization which is set up as a complete manufacturing unit. In this department are made most of the so-called small tools, such as taps, dies, reamers, etc., these tools being made in quantities as distinguished from major tools usually made in lots of one.

These main groups of the major tool room are further subdivided as follows: In the lathe section there are specialists on threading plug gages and master taps, and still others who turn only circular form tools. The bench-work section is subdivided into punch and die work, gage work, and general tool work, including drill jigs, assembling and milling fixtures, screw-machine tools, etc.; and in the die gang there are compound-die makers, tandem-die makers, and forming-die makers, who perform only the bench work necessary in the building of this class of tools.

It will readily be appreciated that in an organization such as that described, producing close to $2,000,000 worth of work a year, some definite means of controlling costs is desirable, and in order to accomplish this control it is necessary to have not only a measure of the operator's performance but also to provide an incentive, no matter how indirect, to inspire the operator to do his best.

The Estimating Plan

One of the methods the company is employing to improve its tool-manufacturing performance, which for want of a better name is called an estimating plan, involves the setting up of an estimated time for each operation on the individual tool parts, and a subsequent comparison with the actual time taken, as a means of rating the workmen and obtaining reliable time values for unit operations of tool construction to be used in connection with time-standardization work for future estimates. This plan has been in operation for the past two years in connection with the manufacture of major tools, and even in its earliest stage of development effected a noticeable increase in efficiency and resulted in lower manufacturing costs. The following description of the plan, which is really still in its infancy, will give some idea of its method of application and the advantages which are being derived therefrom.

Each supervisor prepares a time estimate on each job to be performed in his section, on a special form furnished him for this purpose. These estimates are checked by a group of men in the planning organization, whose approval is obtained before the job is passed out to the workman. The planning engineer then follows the work in process, notes any interruptions or difficulties that may arise, and enters on the estimate form the actual time taken, his opinion of the accuracy of the estimate, and the caliber of the operator's performance. The tool-room supervisor then enters his comments on the form as to the performance given and the accuracy of the estimate. An analysis is made weekly of all the estimate sheets completed and each operator's performance; that is, the total time he required to perform all his jobs compared with the total time allowed for them is recorded on an individual efficiency-rating chart which is summarized into figures at regular intervals and the data used in connection with rate revisions. The workman therefore knows that his pay will depend on his actual performance rather than on the supervisor's judgment.

Meanwhile the operation data thus gathered are classified in a special file for use in compiling time standards for the various classes of work being estimated. In order to illustrate the manner in which these time standards are evolved, the study of compound punch and die work will be analyzed.

The completed estimate sheets on compound punch and die work are classified as far as possible according to type of detail and class of operation. Each estimate sheet, as previously explained, contains the original estimate made by the supervisor before the job was started, the actual time required for each operation, a revised estimate set up by the supervisor after the job is completed, and the planning engineer's estimate. Any

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difference between the estimated and actual time is also explained on the sheet. This information is studied by the planning group, as many similar jobs as are available being used as comparisons, and on this basis the standard-time values for the various compound punch and die operations are established.

As the compilation of time standards for compound punch and die repair work progresses it becomes feasible to determine additional standards by deduction. In other words, in analyzing the estimate sheets to determine the correct time to perform each new operation, the standards already established are deducted from the standard set up for the entire job. To illustrate this method, let us assume that a certain punch and die has been repaired fifteen times and on each occasion an estimate has been made. On ten of these occasions it was only sharpened and a standard of $2^1/_2$ hours set up. On the remaining five occasions, in addition to being sharpened, a broken perforator was replaced and a standard of $3^1/_2$ hours set up. The established standard, therefore, of $2^1/_2$ hours for sharpening, deducted from the standard of $3^1/_2$ hours for both sharpening and replacing a perforator, gives us a standard of one hour for replacing one perforator. In this way overall standards and estimates are broken down into smaller parts in order to make the data applicable to a large range of work.

To further simplify the time standardization and estimating work, folders are compiled containing charts and tables covering all classes of die work, and also a list is made up of all standard tools to be carried in stock, such as automatic stops, die blanks, liner pins, bushings, perforators, etc. The standard methods of operation are also described and a standard-time value for each minor operation common to the majority of die repair jobs, such as dismantling, grinding, assembling, replacing push pins, pilots, perforators, etc., is specified. It is now possible, therefore, to make accurate and reliable estimates on many compound punch and die repair jobs from these standards.

Application of Time Standards

The time standards compiled as just outlined are for minor parts used in compound punch and die construction. For major parts, such as punches, dies, strippers, and shedders, time standards have been built up which cover a sufficient range of work to take care of practically any part regardless of shape or size. The complete standard for punches used on compound punches and dies, for instance, contains the standard bench time for shearing, milling, and stoning, for working out round and irregular-shaped holes, and for performing all other necessary operations. Time values covering such operations as spotting holes, laying out, drilling, and reaming dowel holes, together with time values for milling, filing, and stoning the radii, sharp corners, and straight portions, are also part of this standard.

A folder has also been made up of standard sheets covering all phases of milling work, such as simple mill work, milling cams, verniering, slotting dies and keyways, cutting gears, roughing punches, etc.

To summarize, the control features of the estimating plan just described comprise:

1 A psychological incentive to the operator through the efficiency-rating plan.
2 Better supervision. Under the estimating plan it is the supervisor's responsibility to see that the estimate is met. This has given the supervisor an increased interest in his job, and has immeasurably increased his knowledge of his men and their work.
3 Constantly improving efficiency, brought about by the gradual installation of time or job standards and the increasing efforts of the operators to maintain high ratings by meeting the standards.

During the application of the estimating plan in the tool department there has been a gradual downward trend in both the estimates and the actual performance time, and a noticeable improvement in the application of the men to their work which is resulting in the production of tools in less time than formerly. Simple repair jobs, estimated at six hours when the plan was started and requiring the same amount of time to complete, are now being estimated at one-half this amount, and in a great many cases are being completed in less time than estimated.

Examples Illustrating Economies Effected

To illustrate the economies being effected: A shearing, blanking, and forming punch and die which is used for miscellaneous cord tips was made in 1925 before the installation of the estimating plan. According to the overall cost, approximately 1000 bench-hours were spent in its manufacture. Early in 1926, after the estimating plan had been started, two additional tools of this type were made. They were estimated at 700 hours each and required 506 hours, or 194 hours less than the estimate, and practically 500 hours less than the 1925 figure. These figures are comparable since the development work has been deducted from the total time taken to build the first tool.

Now a point which the author feels is worth emphasizing is that although the time for making this type of tool has already come down 50 per cent, there may still be a possibility of further reasonable reductions. In other words, the next time this type of tool is made it will probably be estimated at around 520 hours, and the actual hours may again be considerably less than the estimated.

A good illustration of this downward trend is shown in connection with a scrapless punch and die for producing brass hexagon nuts. The first estimate, made about a year ago, was 405 bench-hours and the actual time required was 366. A second tool was built shortly afterward and estimated at 350 bench-hours, and the actual time required was 312 hours.

One other case is that of replacing an irregular-shaped punch for an open compound perforating and blanking punch and die. During a year's period, between January 1, 1926, and January 1, 1927, this punch was replaced eight times. The first estimate was $33^1/_2$ hours and the actual time $34^1/_4$ hours. The last estimate was 29 hours and the actual time $21^3/_4$ hours. This punch, which in 1926 required $34^1/_4$ hours to replace, is now being replaced in $21^3/_4$ hours, a difference of 13 hours on a small repair job.

Of course every case does not work out as closely as the foregoing figures would indicate, but in general the results are about as shown.

The psychological effect upon the operators of knowing that they are being graded upon their individual performances from day to day, and that this grade will be used to determine their qualifications at rate-revision periods, has improved their efficiency to a marked degree. The gradual closing-in of the time gap between the estimates, which are daily being lowered, and the standards, which are continually being revised, will ultimately result in obtaining very reliable and efficient time values from which permanent standards will be compiled.

It follows, therefore, that when permanent standards of this kind have been compiled, a valuable step toward the further development of our control methods of tool manufacture will have been developed and a high degree of manufacturing efficiency will have been reached.

Naturally the estimating plan as outlined involves a great amount of detail work, and it was thought advisable when starting it to do it more or less gradually. For this reason it will take some time yet to accumulate sufficient information to set up accurate time standards to cover practically all operations

involved in the manufacture of tools. However, judging from the results already obtained, it is believed that the cost will be repaid many times over and that it is worth doing well.

SMALL-TOOL MANUFACTURE

The plan just outlined is being applied to the manufacture of major tools only. Small tools, on the other hand, represent an entirely different problem, in that this class of work is usually of a more repetitive nature and can be performed by less skilled mechanics, and many of these tools are scheduled in sufficient quantities to warrant paying for them on an incentive basis. In the small-tool department, therefore, piece rates are established by stop-watch timing supplemented by the use of time standards wherever these are available. Piece rates have been built up gradually on this class of work, and to date about 65 per cent of it has been placed on piece work. The results have been very gratifying, as the following figures will show.

Taking as a base the cost of small tools made during the first quarter of 1925, which was previous to the introduction of piece work, the records show that during the first 12 months while introducing piece work there was no gain. This, it should be remembered, was right at the start when very few piece rates had been set. Early in 1926, however, the department began getting gradually into a piece-work stride, and during the second quarter of that year effected its first reduction in costs, amounting to 22 per cent. Since then each quarter has shown very satisfactory savings and averaged for the last four quarters a 46 per cent economy over the results obtained in 1925.

With the estimating plan for major tools and the piece-work plan for small tools under way, the need was felt for some scheme which would give a measure of the overall efficiency, so far as possible, from some bench mark.

ESTIMATING PLAN FOR MAJOR TOOLS

For many years the company estimated the cost of each tool order placed in the shop and compared the actual cost with the estimate. This gave a rough overall check on costs, but it was very rough, and as the estimates were changed to check with recent performances this system gave no check on the year-to-year performance and very little check on individual performance since the estimate was a lump sum and work on each job is performed by several classes of labor.

Therefore a plan was laid out early in 1925 as follows: The first step involved keeping a more detailed record on the performance on each tool order in the shop, which would give, when the job was finished, the following information:

a The time spent on the job by each class of labor, such as milling, turning, grinding, and bench work
b The clock number of each man
c Notes of any abnormal conditions arising, such as errors, parts cracked in hardening, development work, etc.

Such a record was kept over a period of about two years, after which came the next step which involved a careful analysis of these jobs to cull out those affected by special conditions where the extra work could not be evaluated.

This analysis yielded us about eleven hundred jobs, the costs of each job representing the actual performance under normal conditions and the efficiency prevailing during the years 1925 and 1926. These jobs were then associated into cost classes by type of tools; that is to say, all tandem blanking punches and dies costing between $25 and $49 were put in one class, a form giving all data and a photostat copy of the tool drawing constituting the record of each tool.

The association by class and cost gave a further check on the correctness of the costs as figured, as the drawings in each class were again scrutinized to check the consistency of the costs, and jobs that obviously were out of line were thrown out of the record. This record is now finished and will be kept intact without further additions. Of course, other items of standard costs on new tools or tools not made during the period in question are being added, but such further items will always be kept separate from the original list.

This record gives, first, a permanent bench mark as of 1925–1926 from which performance can be measured on individual jobs and from year to year. Secondly, data are being accumulated on the performance of each workman against these former or standard costs. Thirdly, it simplifies the work of estimating future orders for the same or similar tools. Fourthly, it gives the workman a bogey to work against which he knows is something more than a guess on some one's part.

The actual method of use in the tool room is as follows: When an order comes through from the Tool Design Organization that is a duplicate or nearly like one of the tools in the standard cost record, the job is sent to the tool room on a special form which tells the supervisor that this tool, or a similar one, was made previously in so many hours. The order also tells him the names of the workmen who did the previous job and how much time was spent by each.

The workman, knowing that he is being gaged by a previous cost, will naturally make every effort to finish the job in the least possible time. A further incentive is introduced since the worker knows that his performance record is being kept and actually has a great deal of weight at the semi-annual rate-revision periods when the rates of pay of all employees are considered for revision.

An interesting case of this kind arose last June after the new hourly rates were made effective. One of the toolmakers who did not get an increase learned that another man doing similar work did get one. He came up to see the assistant superintendent one day, feeling that an injustice had been done as he was sure he was as good as the other man. He was shown his own performance and also that of the man with whom he was comparing himself. The final result of the conversation was that this man agreed that he had been given a square deal and had no case—and another man who had planned to register a complaint of the same sort decided not to do it.

The effect of such evidence on the general morale cannot help but be good. This man is now satisfied and is doing a better job, whereas had there been no means of measuring his performance he could probably never have been convinced that his failure to get an increase was not due to misjudgment, oversight, or to the possibility that his foreman was prejudiced against him.

Each month a report is gotten out showing the standard cost against the actual cost of all tools finished during the previous month. The first tools on this basis started coming through in January of this year, and the last report, which covers the period up to October 15, shows that the 637 tools which have come through have cost 12.3 per cent less than the standard costs established.

In conclusion, the author would emphasize again that what is being done is nothing more than to make an intensive application of well-known principles, and from experience on other work, it was felt right from the start that the gain in this case would be large. The only feature which may be novel is the method of increasing efficiency in major-tool manufacturing by means of an indirect incentive. Management in general is willing to invest money for improved machinery or methods where it can be shown that the economies effected will return a good rate on the investment. It is the company's firm conviction that the advantages of studies such as the author has outlined, both to the workmen and the company, are very great.

Pittsburgh Engineers Hosts of A.S.M.E.

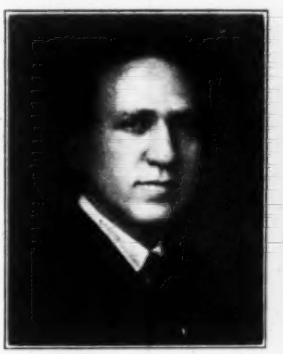
Spring Meeting in Steel Capital Characterized by Technical Sessions of Interest to Local Industries; Excursions to Huge Electric, Steel and Glass Works; Presentation of Holley Medal, Award of Lincoln Welding Prizes, Unique and Varied Entertainment Events

THE 1928 Spring meeting of the A.S.M.E. was held in Pittsburgh, Pa., May 14 to 17, inclusive, with headquarters at the William Penn Hotel. The program consisted of fifteen technical sessions, several meetings of the Council, a conference of Local Sections delegates, a Student Branch conference and luncheon, a great number of committee meetings and special luncheons, instructive and interesting excursions to industries in and about Pittsburgh, and numerous social events.

At the Council Meeting on Monday the budget for the coming fiscal year was adopted, and announcement was made that the 1929 Spring Meeting will be held in Salt Lake City, Utah.

While the total registration for the meeting has been exceeded by that of other Spring Meetings, the technical sessions were unusually well attended. In order that members might take advantage of the numerous excursions offered without missing the technical program, as many as four technical sessions were held simultaneously, and despite the great number of members whose presence was demanded at committee meetings, the attendance at these sessions was large and the discussions extensive and stimulating.

The total registration was 871 and comprised 477 members, 335 non-members, and 59 ladies.



H. E. Rossell

James W. Owens

Henri Dustin

THE LINCOLN PRIZE WINNERS

The Business Meeting

The General Business Meeting of the Society held on Monday afternoon, May 14, was largely given over to the presentation of the Lincoln prizes, offered by J. C. Lincoln and his associates for the best papers on the subject of arc welding.

President Dow introduced Mr. Lincoln, who spoke of the technical advantages of welding as compared with riveting, and of the hesitancy with which welding, like any new process, was being adopted. The papers submitted by the contestants for the prizes had presented many examples of the superiority and economy of the arc-welding process, he said. He was particularly grateful to the committee, upon whom had fallen the arduous task of reading the seventy-seven papers offered in the contest.

L. P. Alford, chairman of the committee of judges awarding the prizes, reviewed the manner in which the papers had been considered by the committee. Eleven papers had been considered of sufficient merit to be read by all of the judges, and an unanimous vote had awarded the first prize of $10,000 to James W. Owens, of the Newport News Ship Building and Dry Dock Co., Newport News, Va., for his paper on "Arc Welding, Its Fundamentals and Economics."

In accepting the award, Mr. Owens took occasion to thank those who had made it possible for him to win the prize—his superiors and associates at the Newport News Shipbuilding and Dry Dock Co., the judges who had reviewed the papers, and Mr. Lincoln who had offered the prize. His winning of it, he said, placed on him a responsibility toward the development of the art. He closed with a graceful and moving tribute to his wife. Mr. Owens' first contact with welding came in 1918, when he became associated with the Welding Research Committee of the Emergency Fleet Corporation. In the fall of the same year he became arc-welding expert at the Norfolk Navy Yard, where he assisted in forming the first welded ship in the Navy in which all the welding processes were employed. In 1926 Mr. Owens left the Navy and became director of welding at the Newport News Shipbuilding Company. Under his direction welding has developed to a point where there are at present about 60 arc and 11 gas welders employed.

Following Mr. Owens' acceptance of the award, C. F. Bailey, Engineering Director, Newport News Shipbuilding and Dry Dock Company, paid a graceful tribute to his colleague and expressed the satisfaction and pride of the company in the award of the first prize to Mr. Owens.

Mr. Alford then announced the award of the second prize of $5000 to Prof. Henri Dustin, of Brussels, Belgium, for his paper "The Fundamentals of Arc Welding." Professor Dustin was unable to be present to accept the award in person.

The third prize was awarded to Commander H. F. Rossell, U. S. N., for a paper on "Electric Welding of Ships, Bulkheads, and Similar Plated Structures." In the absence of the author, the award was accepted by Mr. W. T. Rossell, his brother.

The chairman then stated that the Committee had gone beyond the conditions of the contest and had accorded honorable mention of two other papers, one by Frank B. Walker, Chief Engineer of the Eastern Massachusetts Street Railway Co., Boston, Mass., entitled "Theory and Application of the Base-Plate Arc-Welded Rail Joint," and the other by B. K. Smith, of the Big Three Welding and Equipment Co., Houston, Texas, entitled "Stable Arc Welding on Long-Distance Pipe Lines." In addition to these, the Committee urged the publication of three other papers submitted in the contest.

Following the presentation of the awards, a vote of thanks and appreciation was extended to the judges for their fruitful service.

The Secretary then presented by title the proposed Ameri-

can Standard, "Cast Iron Pipe Flanges and Flanged Fittings."

The Nominating Committee of the Society, presented the following list of nominations for officers for the coming year:

President

Elmer A. Sperry, Chairman of Board of Directors, Sperry Gyroscope Co., Brooklyn, N. Y.

Vice-Presidents

William Elmer, Special Engineer, Pennsylvania Railroad Co., Philadelphia, Pa.

R. L. Daugherty, Professor of Mechanical and Hydraulic Engineering, California Institute of Technology, Pasadena, Cal.

C. L. Gorton, Chairman American Uniform Boiler Law Society, New York, N. Y.

Managers

C. M. Allen, Professor of Hydraulic Engineering, Worcester Polytechnic Institute, Worcester, Mass.

R. M. Gates, Manager, Industrial Division, Superheater Co., New York, N. Y.

E. C. Hutchinson, President, Pelton Water Wheel Co., San Francisco, Cal.

Delegates to the American Engineering Council

Elmer A. Sperry, Brooklyn; E. O. Eastwood, Seattle; Dean E. Foster, Tulsa; W. P. Hunt, Moline; O. P. Hood, Washington, D. C.; Charles Penrose, Philadelphia; Frank A. Scott, Cleveland; Max Toltz, St. Paul; E. N. Trump, Syracuse; and D. Robert Yarnall, Philadelphia.

The Dinner

Up to Wednesday night the ladies had followed an independent program in which the men took no part, but the dinner brought both together. Wits jaded with too much technical detail revived under the stimulus of the Duquesne Light Company's dance orchestra which occupied the stage at one end of the ball room and enticed the more nimble on to the floor during the dinner. Along one side, behind a table covered with flowers, sat the speakers, past-presidents, and distinguished guests, while members of the Society and their ladies, about 300 in all, sat at tables arranged about the dance floor.

After cigars had been lighted, coffee drunk, and a particularly colorful ice consumed, A. N. Diehl, general chairman for the 1928 Spring Meeting, rose to announce the Red Arrow Quartette, and after its offerings, to present the toastmaster of the evening, George S. Davison, past-president of the A.S.C.E. and the Engineer's Society of Western Pennsylvania.

President Dow was the first speaker. He announced the award of the Holley Medal to Elmer A. Sperry for the invention and reduction to practice of the gyroscopic compass, and introduced George I. Rockwood, Worcester, Mass., who instituted and endowed the medal in 1924, and told of the high ideals represented in the achievements which warranted the award "for some great and unique act of genius of engineering nature that has accomplished a great and timely public benefit." The medal was then displayed by the President, and presented by him to the medalist who was received amid enthusiastic applause, the audience rising to do him honor.

Mr. Sperry expressed his gratification and appreciation of the honor done him, and spoke of the high ideals and attainments of the man for whom the medal is named, Alexander Lyman Holley, deceased founder of the Society, and known among steelmasters as the man who introduced the Bessemer process into the American steel industry. Mr. Sperry was gracious enough to demonstrate, with the aid of a small model which he held in his hand, the principle upon which the gyroscopic compass functions, and explained that its accuracy is not affected by changes in time and location.

Toastmaster Davison's introductions of Charles M. Schwab and James Francis Burke, who spoke in place of Wm. L. Munro, unfortunately prevented by illness from being present, were masked with the good-natured raillery which is permissible among friends of long standing. Mr. Schwab had recently returned from England where he had received the Bessemer medal, and was unexpectedly able to accept the committee's invitation to speak. He paid a graceful tribute to Mr. Davison and to Mr. Julian Kennedy (past vice-president A.S.M.E.) who was present at the dinner, and spoke of his cherished associations with the Society. Mr. Burke unleashed his powers of oratory to extol the greatness of Western Pennsylvania in industry, engineering, art, and literature.

Just what an Englishman thinks of America and Americans

Elmer A. Sperry, Holley Medalist

was frankly expressed by Sir Frederick Magill, humorist, who concluded the program of speeches. Dancing followed.

The Excursions

For variety and number of places of interest to mechanical engineers, Pittsburgh is an unusual center. It would be difficult to imagine any member of the Society who would fail to find something of interest in any shop in the district. The local committee, capitalizing this wealth of interesting activity which centers about Pittsburgh, made provision for about thirty excursions. The afternoons of Tuesday, Wednesday, and Thursday were purposely set aside so that the excursions would offer no competition to the technical sessions. To the plants to which visits were made are due the warmest praise and appreciation for their cordial hospitality and the spirit of cooperation with which they assisted in making this important feature of the Spring Meeting a success.

The major trips which received the greatest amount of attention because of their unusual interest, were the trip to the East Pittsburgh works of the Westinghouse Electric & Manufacturing Company, and those to plants typical of Pittsburgh's most famous industries, steel and glass.

On Tuesday afternoon the excursion covered the plants of the U. S. Steel Corporation, which lie along the Monongahela River. Starting at the Homestead works, the party was carried in open gondola cars over the Union R.R., a subsidiary of the U. S. Steel Corporation, to the Clairton Works, where the trip ended.

The following plants and points of interest were visited: Carrie furnaces, Central Rock, Edgar Thomson works, coal docks, Duquesne works, slag dumps and slag-preparation plant, the marine ways, and the Clairton by-product coke works. The coke ovens, blast furnaces, and blooming mills were tremendously impressive to those seeing them for the first time, and awoke renewed interest in the others.

At the Westinghouse Electric & Manufacturing Co., on Wednesday afternoon, the visitors had the opportunity of seeing the immense works founded in 1886 by George Westinghouse. The manufacturing side of a great electrical industry which varies in scope from small parts under mass-production methods to electric locomotives, generators, and transformers of large size and special design was fully illustrated.

On Thursday afternoon interest centered around the excursion to the Jeanette plant on the American Window Glass Company, the largest of the company's plants. Here were seen two of the largest glass-smelting furnaces in the world, each furnace containing 1800 tons of molten glass and producing 3240 fifty-foot boxes of window glass per day. The technique and methods involved in the glass industry were interesting and novel to the majority, who saw for the first time how a common commodity was made.

Local committees at other Spring Meeting headquarters will find it difficult to offer in variety and number such excellent excursions as were offered at Pittsburgh.

THE LADIES' PROGRAM

Some day a genius will arise in the land and will confer great benefits on the average citizen and his brother-engineer by making the social and economic features of engineering so absorbing and of such vital interest that no intelligent person can be indifferent to it without admitting an unforgivable ignorance. At present the fraternity of engineers speaks a mystic language which few understand, and interests itself in details quite incomprehensible to the world at large. Small wonder, then, that a program of special events is provided at A.S.M.E. meetings for the entertainment of the ladies.

While Pittsburgh as a resort may not have the appeal to feminine fancy that has made White Sulphur Springs linger in their memories, it holds interests of another character. With a headquarters of its own on the club floor of the William Penn Hotel, the sub-committee on Ladies Events provided delightfully for the 59 ladies during the four days of the meetings.

Monday afternoon was devoted to a visit to the Carnegie Museum, and the evening to a special performance given at the Little Theatre, Carnegie Institute of Technology. Tuesday, after a luncheon at the Long Vue Country Club, there was an automobile drive through some of the residential districts of the city. Of special interest was the trip on Wednesday afternoon to the plant of the H. J. Heinz Company. An informal tea bridge at the Women's City Club completed the program on Thursday afternoon.

The success of the ladies' program was due to the efforts of the local committee, of which Mrs. John A. Hunter was chairman. The other members of the committee were Mrs. A. N. Diehl, Mrs. T. A. Peebles, Mrs. Alfred Hurlburt, Mrs. Morris Knowles, Mrs. K. F. Treschow, and Mrs. H. B. Mann.

Technical Sessions

General Session

THE General Session, held on Monday afternoon, May 14, with John H. Lawrence, Vice-President and Engineering Manager, Thos. E. Murray, Inc., New York, and Vice-President, A.S.M.E. presiding, attracted a small but interested audience. The paper by Walter S. Weeks and Pierre E. Letchworth, Department of Mining and Metallurgy University of California, Berkeley, Calif., entitled "The Reciprocating Dry-Vacuum Pump," was presented by J. S. Fulton, of the Ingersoll-Rand Co., Pittsburgh, Pa. It was a study of the number of strokes that must be made by a pump to produce a given pressure in a tank, and presented a formula developed by the authors, with a discussion of the experiments performed to test its accuracy.

H. G. Reist, Designing Engineer, Alternating-Current Machinery, General Electric Company, Schenectady, New York, presented the second paper, entitled "Plate-Steel Rotor for an Electric Generator." He explained the construction of a 220-ton revolving-field spider for a generator driven by a vertical water wheel. This paper appeared in the May, 1928, issue of MECHANICAL ENGINEERING. B. A. Behrend, Consulting Engineer, Wellesley Hills, Mass., sent in a written discussion, which was read following the presentation of the paper. Carl R. Soderberg, of the Westinghouse Electric & Mfg. Co., showed a photograph and a drawing which illustrated the methods employed by his company in building up rotors involving the use of considerable plate steel.

Fuels and Heat Flow Session

A. G. CHRISTIE, Professor of Mechanical Engineering, Johns Hopkins University, presided at the session on Fuels and Heat Flow on Monday afternoon. The opening paper of the session treated the subject "The Flow of Heat Through Furnace Hearths," and was presented by the author, J. D. Keller. Non-ventilated types of furnace hearths were discussed and conclusions as to relations of heat flow to shape and construction were given. Methods of calculations followed to obtain the conclusions shown were also reviewed.

Two very interesting and valuable papers on powdered fuel followed. The first, "The Use of Pulverized Coal in Basic Open-Hearth Furnaces," by E. L. Herndon, gave an account of experiences of the Eastern Steel Co., Pottsville, Pa., over a long period of time in the use of pulverized coal in its basic open-hearth furnaces. Immediately following this paper, F. G. Cutler reviewed some results obtained at the Ensley blast-furnace plant of the Tennessee Coal, Iron, and Railroad Company on six blast furnaces, in his paper on "Combination Firing of Blast-Furnace Gas and Pulverized Coal." The plant described has been operating a boiler plant using pulverized coal to supplement blast-furnace-gas firing for about five years.

The first paper was discussed at some length, both written and oral comments being offered. The powdered-coal papers were discussed jointly, and the additional information contributed should add greatly to the value of the papers.

Management Session

THIS session, which was held under joint auspices of the Management Division and the Pittsburgh Section of the American Ceramic Society, was productive of considerable interesting discussion. The one paper of the session, on "Systems of Workman Payment in Porcelain Factories," was presented by its author, Hobart M. Kraner, Ceramic Engineer of the Westinghouse Elec. & Mfg. Co., East Pittsburgh.

W. Keigh McAfee, Vice-President of the Universal Sanitary

Mfg. Co., New Castle, Pa., presided over the session and drew out a great deal of discussion on nearly all phases of application of incentive systems to ceramic plants. The discussion emphasized the fact that the great difficulty involved was the securing of an incentive system for increased production which would not impair the quality; and further, that management in the industry was much handicapped by the lack of scientific and engineering knowledge and control over materials and production methods.

Session on Education and Training for the Industries

THIS session was held on Monday afternoon, before an audience that filled the room to capacity. The paper on "Training Minor Executives in a Rapidly Growing Organization" was ably presented by its author, A. J. Beatty, Director of Training of the American Rolling Mills, Middletown, Ohio, and the meeting was presided over by Dean R. L. Sackett in his usual efficient way.

The discussion of the paper was led by R. G. Forbes, Supervisor of Instruction, National Tube Company, Ellwood City, Pennsylvania. Mr. Forbes stated that in the planning of an operating training course for minor executives three primary factors should be included: the careful selection of applicants for the course, the content of the curriculum, and the most advantageous time for conducting the classes both from the standpoint of the management and that of the student.

C. S. Coler, Manager of the Educational Department of the Westinghouse Electric & Manufacturing Company, brought out the point that executive ability requires three things: first, length of vision; second, breadth of information and experience; and third, depth of understanding of human nature. Mr. Coler felt that the program as outlined by the author was well calculated to develop these qualities as opposed to the older methods of creating executives, which were fundamentally sink-or-swim methods. He also wished to bring out that under present methods the first thing to take into consideration is the very careful selection of men coming into the plant, and secondly, careful records and reviews from time to time. He was emphatic that responsibility should be given to men as early as possible—saying that the acceptance of responsibility is the keynote of executive ability.

R. L. Kirk, Assistant to System Development Engineer of the Duquesne Light Company, felt that a very important fact in the training of executives is to have a sympathetic attitude. Also that suggestion contests within an organization bring out executive ability.

Seamless Tubing Session

IT WAS to be expected that in a great steel center the session of the new Iron and Steel Division should meet with popular response.

The subject of the session, "The Manufacture of Seamless Tubes," was well presented in a paper of that title prepared by R. C. Stiefel and George A. Pugh, Consulting Engineer and Vice-President, and Assistant Vice-President, respectively, of The Aetna Standard Engineering Company, Youngstown, Ohio. Mr. Pugh presented the paper which discussed the two methods of manufacturing seamless tubing of 4 in. and greater diameter, namely, the pilger process, and the automatic or plug-mill process; while Mr. Stiefel closed the discussion by illustrating certain features of the design of the mills on which questions had been asked by various discussers.

Among those contributing to the discussion were Prof. W. Trinks, of Carnegie Institute of Technology, W. Marshall Selkirk, Chief Engineer of Pittsburgh Steel Products Co., Monessen, Pa., H. H. Murray, Supt. of the Babcock & Wilcox Tube Co., Beaver Falls, Pa., J. B. Wharton, Chief Engineer, Standard Seamless Tube Co., Braden, Pa., and W. R. Clark, Genl. Wks. Mgr., Bridgeport Brass Co.

The session was presided over by A. N. Diehl, Vice-President of the Carnegie Steel Company.

Railroad Session

THE Railroad Session, under the auspices of the Railroad Division, was held on Tuesday Morning, May 15, D. F. Crawford, Consulting Engineer, Standard Stoker Co., Inc., Pittsburgh, Pa., serving as chairman.

The first paper, entitled "Locomotive and Freight-Car Utilization," by C. B. Peck, Managing Editor, *Railway Mechanical Engineer*, brought forth favorable comment from those who discussed it. Louis E. Endlsey, Professor of Railway Mechanical Engineering, University of Pittsburgh, led the discussion. Wm. Elmer, Special Engineer, P.R.R., Philadelphia, presented the railroad point of view. Roy V. Wright, Managing Editor, *Railway Age*, New York, and A. Stucki, Engineer, Pittsburgh, Pa., also submitted comments.

A historical résumé of the air brake, illustrated by numerous lantern slides, was presented by L. K. Sillcox, Assistant to the President, N. Y. Air Brake Co., Watertown, N. Y., in a paper entitled "Power Brakes and Modern Train Operation." Prof. S. W. Dudley, Department of Mechanical Engineering, Yale University, commented at length on the paper. Roy V. Wright, was impressed with the mechanism of the air brake and its extreme sensitiveness and reliability. Was it not time, he argued, for the rest of the freight car to be subjected to the same degree of refinement in design with a view to improving its operating characteristics?

In his presentation of a paper on "Locomotive Sparks," L. W. Wallace, Executive Secretary, American Engineering Council, Washington, D. C., told of his extensive tests to determine scientific data on the behavior of sparks from locomotives, and some of his experiences in legal cases arising out of fires alleged to have been caused by sparks. He urged railroads to a more serious consideration of this important subject.

Wm. Elmer, discussed another phase of locomotive sparks. He told of the great expense to railroads of keeping the road ballast clean, and said that it had been noticed that cinders and sparks contributed greatly to the fouling which made this cleaning process necessary.

Hydraulic Session

ONE of the most interesting sessions of the meeting, in point of discussion, was that held under the auspices of the Hydraulic Division on Tuesday morning. After the session was called to order by the chairman, R. L. Thomas, Assistant to the General Superintendent of the Pennsylvania Water and Power Co., Baltimore, Md., two papers, "A Water-Level Gage of Long-Distance Recording Type," by E. B. Strowger, and "Computation of the Tail-Water Depth of the Hydraulic Jump in Sloping Flumes," by Robert W. Ellms, were presented. Mr. Strowger described an instrument consisting essentially of two Selsyn motors, one called the transmitter and the other the follower, which has been in successful operation over a sufficient period of time to convince the users of its merits. A recording device produces a permanent record of the water-level variations over any desired period. The discussion brought out suggestions for other devices of different character, ranging from alarms to

warn of dangerous levels, to recording devices operated on principles entirely different from those described by the author. One of the objectionable features of the electrically operated remote gage proved to be the number of wires required. Some of those present felt that the expense would prove a considerable item, while others argued that the amount of investment was well justified, when the value of the plant was considered.

Mr. Ellms presented considerable data on the hydraulic jump, and mentioned a few of the uses to which it is put. This paper provoked considerable discussion, and it seems probable that there will be additional comments in writing from members of the Hydraulic Division before the paper is finally published by the Society.

Glass Session

ALTHOUGH a subject in which every one has more or less interest, glass has been given very little time in engineering meetings. The Pittsburgh Spring Meeting Committee, however, made provision for a session on this very important branch of industry, and the session on Wednesday morning drew a splendid attendance. The chairman, Prof. W. Trinks, of the School of Mechanical Engineering, Carnegie Institute of Technology, was able to draw out a great deal of valuable discussion.

But one paper was scheduled for presentation: "Some Recent Developments in the Manufacture of Flat Glass," by H. K. Hitchcock. However, two prominent glass experts were invited to discuss the paper, and the first, J. W. Cruikshank, offered his comments in written form, which practically amounted to a second paper. H. L. Dixon followed with an extemporaneous treatment of the subject in which he covered many of his personal experiences and many of the later developments in the art. He also illustrated by means of blackboard sketches a plant operated by the Ford Motor Company at River Rouge, and pointed out wherein it differed from earlier types.

Machine Shop Practice Session

AT THE Machine Shop Practice Session, presided over by E. R. Norris, General Works Manager, Westinghouse Elec. & Mfg. Co., the first paper presented was one on "Some Common Delusions Concerning Depreciation," by Ernest F. DuBrul, General Manager, National Machine Tool Builders Association, Cincinnati, Ohio. Mr. DuBrul's remarks were pointed and secured the desired result in bringing out ample discussion, among those who contributed being President Alex Dow. The paper was printed in the May issue of MECHANICAL ENGINEERING.

The second paper, on "Ball-Bearing Machine-Tool Spindles," by Thomas Barish, Asst. Chief Engineer of Gurney Division of the Marlin-Rockwell Corp., Jamestown, N. Y., reviewed three types of these spindles now in use, showing how rigidity is obtained and what results are secured. Among those who discussed the paper were, Walter H. Trask, Jr., Salt Lake Hardware Co., Salt Lake, Utah, F. E. Cardullo, of G. A. Gray Co., Cincinnati, Ohio, H. B. Schell, of M. D. Knowlton Co., Rochester, N. Y., and Wilson P. Hunt, of the Moline Tool Co., Moline, Ill.

Applied Mechanics Session

NOT the least impressive feature of the Pittsburgh meeting was the enthusiasm which was displayed at the two sessions on Wednesday and Thursday mornings which were devoted to applied mechanics. George M. Eaton, Engineer, Molybdenum Corporation of America, Pittsburgh, Pa., chairman of the Applied Mechanics Division which sponsored these technical sessions, presided, and drew from his audience much helpful discussion of papers which were highly technical.

The first paper, by H. M. Westergaard, Professor of Theoretical and Applied Mechanics, University of Illinois, Urbana, Ill., and Wm. R. Osgood, Assistant Professor of Structural Engineering, Cornell University, Ithaca, New York, was entitled "Strength of Steel Columns," and developed the theory applicable to steel columns which are stressed beyond the proportional limit and which are eccentrically loaded or initially curved. It was discussed by Prof. A. Nadai, of the University of Göttingen, for the present associated with the Research Department of the Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa., Carl R. Soderberg, also a Westinghouse engineer, Prof. S. Timoshenko, of the University of Michigan, and the chairman, George M. Eaton.

The second paper, entitled "The Theory of the Dynamic Vibration Absorber," by T. Ormondroyd, Motor Engineering Department, and J. P. Den Hartog, Power Engineering Department, Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa., was presented by Mr. Den Hartog. There was much written discussion of the paper by Professor Timoshenko, Max Patitz and Robert F. Vogt, of the Allis-Chalmers Mfg. Co., Milwaukee, Wis., Lydik Jacobsen, of Leland Stanford University, A. L. Kimball, of the General Electric Company, Schenectady, N. Y., L. B. Tuckerman, of the Bureau of Standards, Washington, D. C., Webster Tallmadge, of New York, Prof. E. O. Waters, of Yale University, Morris Stone and Carl R. Soderberg of the Westinghouse Company, and M. W. Torbet of the American Brown Boveri Electric Corporation, Camden, N. J.

Thursday's session considered two papers, one by Lydik S. Jacobsen, Assistant Professor of Mechanical Engineering, Leland Stanford Junior University, Stanford University, Calif., entitled "Torsional Stress Distribution in Prismatical Bars;" and the other by Fritz Lowenberg, of the Delling Motors Co., Camden, N. J., on "Stresses in the Drive System of Three-Cylinder Locomotives."

In discussing the paper by Professor Jacobsen, Carl R. Soderberg told of the success which had attended the practical application by the Westinghouse Company of the stress analysis of shafts with fillets, which had been reported to the Society in a previous paper by Professor Jacobsen. Morris Stone pointed out some possibly fruitful lines of investigation for the consideration of the author.

The paper by Mr. Lowenberg brought out a discussion from A. I. Lipetz, Consulting Engineer of the American Locomotive Company, Schenectady, N. Y., and a written communication from R. Eksergian, Engineer, Baldwin Locomotive Works, Philadelphia, Pa. H. A. Houston and B. Wheeler of the Westinghouse Company described a device for measuring instantaneous stresses in locomotive main rods. James Partington, American Locomotive Co., New York, also discussed the paper.

The discussions of the papers were in most cases written and will appear later in the Transactions of the Society.

Materials Handling Session

WHILE but one paper was delivered at this session, namely, "A Materials-Handling and Transport Organization," by C. A. Fike, Supervisor of Transportation, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa., there was nevertheless an extreme amount of interest shown in its presentation and discussion.

In the discussion that followed, G. W. Ashman, of the General Electric Company, Schenectady, N. Y., gave some very inter-

esting comparisons between the G. E. procedure and that of the Westinghouse Company, stressing particularly unit costs. He also brought out the point that he believed that the tractor and trailer system is the most economical.

Wm. Elmer, of the Pennsylvania Railroad, called special attention to the work of the Department of Commerce in developing the interplant cost not only between the buildings of the plant but also between various plants which may be operated by the same company in different cities; and particularly to the skid system, a system which the author of the paper had brought out was being used in his plant and that a certain type of skid had been standardized. Mr. Elmer further brought out the fact that the total bill for materials handling in this country for 1926 was given as four million dollars, but when the cost of handling materials carried out in small lots was segregated, there were various estimates, usually around a billion dollars a year, which amount could be very much reduced by employing such methods as had been developed in the paper. P. W. Power, of the General Electric Company of Pittsfield, Mass., in his discussion endorsed the tractor-and-trailer method, and described his company's experience with wheels. After considerable experimentation, he said, rubber tires had been adopted exclusively.

Session on Engineering Education

PRESIDENT Thomas S. Baker of Carnegie Institute of Technology occupied the chair at the Session on Engineering Education held Wednesday morning.

In the opening paper, on "Industrial Cooperation in Education," the author, A. C. Jewett, emphasized the need for more training for all industrial employees and pointed out how simply and inexpensively this training can be obtained if the industries cooperate. He also presented a large amount of interesting data concerning the extent to which night-school training is carried on in the Pittsburgh district. The discussion on this paper was opened by Roy V. Wright, managing editor of *Railway Age*, who outlined the steps taken to foster industrial education in the railroad field. Prof. Charles F. Scott, of Shepherd Scientific School, analyzed the statistics presented by Mr. Jewett and drew as his conclusion that the industries which are generally prosperous encourage their employees to take up outside training. William R. Webster, of the Bridgeport Brass Company, emphasized the difficulty of securing competent teachers. F. C. McLaughlin, of the International Correspondence Schools, stated that in the Pittsburgh district where education is given attention by management and where there are wonderful night schools, the correspondence-school courses are also well patronized. C. S. Coler stated that one-third of the employees of the Westinghouse Company at East Pittsburgh are taking courses of one kind or another.

The second paper of the morning, on "Education and Training as Applied to the Engineer," was presented by Dean F. L. Bishop, of the University of Pittsburgh, and secretary of the Society for the Promotion of Engineering Education. Dean Bishop's paper brought out a large amount of interesting discussion which was led by W. E. Wickenden and participated in by Dean A. A. Potter, Prof. C. F. Scott, Alex Dow, President A.S.M.E., Dean R. L. Sackett, C. S. Coler, W. A. Dick, William R. Webster, and O. W. Boston. This paper with the discussion will appear in an early issue of MECHANICAL ENGINEERING.

Central Station Power Session

MEMBERS seem to have come to expect good attendance at a session on central stations or anything dealing with power generation. The Central Station Power Session, on Thursday morning, proved no exception to the rule, for the largest attendance of the meeting was recorded. Past-President W. L. Abbott presided.

H. Boyd Brydon presented the first paper under the title "Some Economic Factors in Power-Station Design," in which he discussed capacity factors and average loads of steam turbines over a sixteen-year life period and examined the cost of seven 60,000-kw. unit plants, one operating at 400 lb., three different combinations at 600 lb., and three at 1200 lb. His conclusions favored the 400-lb. plant which elicited a volume of discussion from a prominent group of designing and operating engineers.

Geo. A. Orrok followed with his contribution on "High-Pressure Steam Boilers." This paper presented a study of the principles underlying the design and construction of the high-pressure steam boilers. Among the problems receiving attention were the effect of tube inclination; circulation; releasing surface and steam space; safety in operation; increase in capacity; boiler materials; temperature margins; and stresses in superheater tubes, riveted drums, and headers.

The amount of discussion was so great that there was not sufficient time to present all contributions, although in many cases abstracts were offered. The discussion will be given in full in the Transactions.

Alloys Session

THE Alloys Session on Thursday morning showed the keen interest which engineers are taking in the possible uses of various alloys, especially in bearings.

The first paper to be presented, on "Mechanical Properties of Aluminum Casting Alloys at Elevated Temperatures," was prepared by R. L. Templin, Chief Engineer of Tests, C. Braglio Testing Engineer, and K. Marsh, Chief of Pyrometric Division, Aluminum Co. of America, Pittsburgh, Pa. Mr. Templin presented the first part of the paper which covered work the company had accomplished during the past six years in determining the mechanical properties of various alloys at elevated temperatures. Mr. Marsh presented the second part, which dealt with the methods used to measure the temperature of the specimens, so that those interested might be able to check or judge for themselves of the accuracy of the results.

J. M. Lessells, Mechanics Section of Westinghouse Elec. & Mfg. Co., led the discussion and was followed by P. G. McVetty, Research Department of the same company. F. M. Brauer, of the Watertown Arsenal, discussed the need for a light-metal alloy in important components of a gun carriage.

A. W. France questioned if it were possible to use aluminum alloys for piston and packing rings in view of the increasing use of high temperatures.

The second paper, "A Study of Tin-Base Bearing Metals," by O. W. Ellis and G. B. Karelitz, Research Dept. of Westinghouse Elec. & Mfg. Co., discussed the results of metallographic and mechanical tests on a series of tin antimony-copper alloys containing up to 10 per cent of antimony and 8 per cent copper. Mr. Templin discussed data secured on Brinell hardness tests. P. W. Beace, Research Engineer of Westinghouse Elec. & Mfg. Co., raised a question as to what type of duplex structure was best for bearings. Mr. Ellis, in closing, stated that at the present time no recommendation as to any specific alloy that would be suitable for any particular purpose could be made. The paper represented only the first part of the authors' work, and what they had endeavored to do was to find, if possible, the simplest all-round method of determining the characteristics of any given alloy of this particular system. They felt that the evidence showed that the Brinell hardness test very satisfactorily represents certain of the other properties which mechanical

engineers quite frequently look upon as essential in their bearing metals.

Others who contributed to the discussion were A. L. Davis, Research Engineer, Scovill Mfg. Co., Waterbury, Conn., P. W. Cadman, of the A. W. Cadman Mfg. Co., Pittsburgh, Pa., and H. B. Schell of the M. D. Knowlton Co., Rochester, N. Y.

The session was presided over by William R. Webster, Vice-President of the Bridgeport Brass Company, Bridgeport, Conn., who also contributed to the discussion on both papers.

Technical Committee Meetings

TWENTY of the Society's technical committees took advantage of the Spring Meeting to hold sessions. These sessions were attended by over 200 persons. Seven research committees with an attendance of over 60 participated in this group of meetings.

RESEARCH COMMITTEE MEETINGS

The Main Research Committee started things off with its regular quarterly meeting on Monday morning. Among other items of business transacted was the approval of a plan whereby the Local Sections may aid and participate in the research activities of the Society. The recent distribution to the engineering schools of the country by the Main Committee of a group of research suggestions for undergraduate and graduate-student thesis investigations was reported as very favorably received, and consideration is being given to a plan whereby substantial prizes may be established for the solution of such problems. The Main Committee also considered at this time a proposal for closer cooperation between Technical Committees and Professional Divisions operating groups through a special joint meeting held each year.

At the meeting of the Boiler Furnace Refractories Committee the same morning, Messrs. R. A. Sherman and E. Taylor, research fellows, reported their conclusions on the field investigations which they have carried on during the past four years in some 40 central stations. The laboratory phase of the committee's program is progressing at the University of Illinois and the Ceramic Laboratory of the Bureau of Standards, at Columbus, Ohio. An investigation into the viscosity-temperature reactions of coal-ash slags is being planned.

On Tuesday morning representatives of the various sub-committees of the Fluid Meters Committee met to discuss progress being made in completing Parts 2 and 3 of the Fluid Meters Report. Of the experimental work now being conducted by this Committee the joint program recently arranged with a similar committee in Germany on the development of the dimensional-analysis section of the Fluid Meters Report, is of particular interest.

Two committees met on Wednesday morning, that on Lubrication and that on Mechanical Springs. Plans were formulated by the former committee for a cooperative investigational program on lubrication to be carried on at the Westinghouse Co., Pennsylvania State College, and the Bureau of Standards. Since completing its viscosity measurements at high pressures the committee has been conducting experimental work at the Bureau on the relation between journal-bearing design and lubrication performance. This work will be reported at the Lubrication Session during the coming Annual Meeting. The solicitation of funds to continue this work as well as extensive studies on "oiliness" phenomena is to be undertaken shortly.

The Mechanical Springs Committee reviewed the progress of the experimental work on the development of a Code of Design now being conducted by A. Hoadley, its research fellow, at Union College, Schenectady, N. Y. Announcement was made of an experimental program to be conducted for the committee by the U. S. Naval Experiment Station on fatigue and fatigue-corrosion properties of spring materials. It was also reported that the series of plant visits recently made by various members of the committee had been very fruitful in revealing and clarifying the spring problems of industry and its live interest in this committee's work.

Twenty-five members and guests attended the luncheon meeting of the Cutting of Metals Committee on Thursday. The sub-committee on Cutting Fluids reported progress in the analysis and correlation of data collected from industry both here and abroad on the relation between the physical and chemical characteristics of cutting fluids and their performance. This sub-committee will also shortly undertake a series of quantitative test on typical types of cutting oils to reveal tool-penetration quality, lubrication or oiliness, cooling, and cutting performance associated with finish. The sub-committee on Properties of Materials submitted a test code for high-speed turning tools for medium roughing work which is to be considered for recommendation as a standard. A sub-committee on Bibliography was formed, Prof. O. W. Boston, chairman, which through the contacts of its members will attempt the collection and correlation of existing foreign and domestic literature on research in metal cutting. The sub-committee on Machinability of Metals is considering the formulation of recommended practice sheets on the subject as related to commercial practice. Experimental work on machinability is being carried on by the various members of this sub-committee.

STANDARDIZATION COMMITTEE MEETINGS

The Standardization Committee held its third quarterly meeting with full attendance. The most important business of the meeting was the discussion of new standardization projects, seven of which were decided upon for presentation to the American Engineering Standards Committee.

The organization meeting of the Sectional Committee on Wrought-Iron and Wrought-Steel Pipe and Tubing was held on Friday, at the William Penn Hotel. Prof. Collins P. Bliss, chairman of the A.S.M.E. Standardization Committee, presided. The meeting was well attended, twenty-eight men being present, and the work of the new committee started. Harold H. Morgan, District Manager, Robert W. Hunt Company, was elected temporary chairman, and Sabin Crocker, Designing Engineer, Detroit Edison Company, temporary secretary. In addition to these elections four sub-committees were designated: (1) Plan, Scope, and Editing; (2) Pipe and Tubes for Low Temperatures; (3) Pipe and Tubes for High Pressures; and (4) Materials.

The Sectional Committee on the Standardization of Small Tools and Machine-Tool Elements held a luncheon meeting preceding their regular business meeting on Tuesday. The meeting was most successful for the large number of members present and the amount of new business accomplished. The most important items were the appointment of the Executive Committee and the approval of two new projects, namely, the standardization of twist-drill sizes and of punch and die holders.

The Technical Committee on the Standardization of Machine Tapers held a large meeting on Tuesday morning. Chairman DuBrul reported that the replies to the questionnaire circulated by the A.S.M.E., S.A.E., and N.M.T.B.A. indicated that a single standard taper was desirable. The suitability of existing tapers was discussed, but none could be decided upon. Several of the committee favored the complete abandonment of all existing tapers in developing the standard, while the remainder, who were a small majority, favored the retention of portions of existing taper series which have been used for a considerable length of time and found to be satisfactory. A committee of

Those Who Made the Pittsburgh Spring Meeting a Success

SPRING MEETING COMMITTEES

Sub-Committees for 1928 Spring Meeting

A. N. Diehl, *General Chairman*

Finance
- H. R. Cornelius
- C. W. Bennett
- O. P. Reese
- J. I. Thompson
- J. H. Fox, *Chairman*

Technical Sessions
- G. G. Bell
- G. M. Eaton
- H. S. Heichert
- T. E. Purcell
- W. Trinks
- J. A. Hunter, *Chairman*

Printing and Signs
- G. D. Bradshaw
- E. D. Dreyfus
- R. E. Butler
- G. G. Bell, *Chairman*

Hotels
- W. D. Canon
- A. B. Severn
- E. C. Shriner
- K. F. Treschow, *Chairman*

Entertainment
- F. R. Phillips
- E. J. Lang
- L. E. Young
- R. M. Flocker
- B. Stevenson, *Chairman*

Excursions
- A. Pinkerton
- H. B. Mann
- J. R. Tanner
- A. Hurlburt, *Chairman*

Information—Registration
- G. E. Dignan
- Louis Ellman
- T. G. Estep
- W. N. Flanagan
- R. M. Overton
- T. A. Peebles, *Chairman*

Publicity
- W. T. Mossman
- Wm. French
- T. C. McQuiston
- F. R. Magill
- R. A. Mitchell
- Morris Knowles, *Chairman*

Reception
- R. W. Andrews
- H. B. Kirkpatrick
- Kenneth Seaver, *Chairman*

Ladies' Events
- Mrs. A. N. Diehl
- Mrs. T. A. Peebles
- Mrs. Alfred Hurlburt
- Mrs. Morris Knowles
- Mrs. K. F. Treschow
- Mrs. H. B. Mann
- Mrs. J. A. Hunter, *Chairman*

five consisting of both theoretical and compromise proponents, was appointed to prepare a taper series for presentation at the next meeting.

The Sectional Committee on the Standardization of Plain and Lock Washers held a very active meeting at which C. W. Squier, Associate Editor, *Electric Railway Journal*, was elected chairman, and E. R. Dowdy, Works Manager, Washer Manufacturing Company, secretary. The committee voted for two Sub-Committees, (1) on Plain Washers and (2) on Lock Washers.

The Sectional Committee on the Code for Pressure Piping held a well-attended meeting on Wednesday morning. At that time the preliminary drafts of Sub-Committee reports were discussed and recommendations made.

At the meetings of the Sub-Committees on Power Piping and Fabrication Details, the reports which were to be submitted to the Sectional Committee on a Code for Pressure Piping were discussed and revised. Both meetings were well attended.

Sub-Committee No. 5 on Line Work and No. 6 on Graphical Symbols of the Sectional Committee on Drawings and Drafting-Room Practice met on Monday and Tuesday mornings. These Sub-Committees discussed their preliminary recommendations and the Wednesday meeting terminated in a joint meeting of both Sub-Committees.

The Sub-Group on the standardization of Loose Flanges met on Friday afternoon and discussed the proposals which were submitted for incorporation in this standard. The formulas which have been developed for flange width and thickness and which gave results agreeing very closely with those obtained by actual test were considered and approved.

The Sub-Committee on Rigid Conduit of the Sectional Committee on Pipe Threads held their first meeting on Tuesday afternoon. The session involved initiating procedure for its activity and correlating the material already presented.

An Automatic Fireless Lehr

A LEHR is a device used in glass making for annealing the glass, particularly bottles. The present type was developed by the Thermal Engineering Co., Fairmont, W. Va., and a unit was installed in November, 1926, at the Peerless Glass Co., Long Island City, N. Y. Since then three similar lehrs have been installed in the same plant. One of the characteristics of this type of lehr is that it combines simplicity with automatic operation. It is equipped with a roller conveyor which stacks or distributes the bottles in the lehr. This is done by means of the so-called "ushers" which comprise the distributing device and eliminate the labor of the carrying-in boy. The rollers are driven on both sides of the lehr by means of small sprockets and sprocket chains, giving the lehr a constantly changing bottom contact. From the mold, the bottles are transferred to the top of a pneumatic elevator which raises them as soon as it is released to the level of the revolving roller conveyor. A device called the "wipe-off" automatically slides the article on to the conveyor, which carries it through an opening in the front wall just big enough to admit the article.

The annealing operation after the first heating up of the annealing zone for the Monday morning start is a fuelless one. The bottle enters sufficiently cool to keep its shape, but containing enough heat, if conserved, to anneal itself while passing through the soaking and annealing chambers. It is claimed that from actual results obtained at the Peerless glass plant 97 to 98 per cent of the shear cut that comes through is perfectly annealed.

When the bottle touches the first usher of the several comprising the distributer, it gives the finger at the bottom of the supporting usher rod a gentle push and is itself gently guided to the right or left side, as required, coincidently moving forward on the conveyor toward its place in one of the rows beyond the usher. Meantime the usher is left in position to pass the next bottle to the opposite side. A little further on the bottle meets other ushers, each of which forms two new rows, and so on, until, in these particular machines there are twelve rows of bottles going through at one time.

Experiments are under way to control the stacker by means of timers on the upper outside ends of the usher arms which support the ushers from the roof of the chambers, so that when it is desired to have several bottles follow the same straight line instead of being turned aside alternately, it will be possible to pass two or three consecutive ones to the same row. (*The Glass Industry*, vol. 9, no. 5, May, 1928, pp. 99–103, *d*)

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

AERONAUTICS

Aviation in Continental Europe

IN GERMANY there are 76 regular air lines, all controlled by the Deutsche Luft Hansa or by companies affiliated with it. Passenger fares are about the same as first-class fares on express trains. In 1926 a total of 56,268 passengers, in addition to freight and mail, were carried. The companies receive a large subsidy from the government.

As regards airships, the most interesting are the data referring to the LZ-127 now under construction. This dirigible is designed as a commercial airship with a range of about 6000 miles. It will be able to carry 20 passengers and 15 tons of baggage, mail, and freight. The dimensions of the ship were made as large as the dimensions of the construction shop permitted. Its total length will be about 774 ft., with a maximum diameter of 100 ft. and a maximum height of 110 ft. There is a nominal gas capacity of 3,709,000 cu. ft.

The total maximum engine power will be 2650 hp., giving the ship a speed of 80 m.p.h. Under normal atmospheric conditions the total lifting capacity of the ship will be 129 tons with a speed of from 62 to 68 m.p.h. The crew will include 26.

The power plant will use either gasoline or gaseous fuel. This power gas will be carried in special bags in the lower part of the hull, while the upper part will hold the bags for the lifting gas. The gas bags are provided with large automatic valves to prevent pressures from becoming unduly high. Heavy carbohydrates will be used as gaseous fuel. The weight of these gases is about equal to that of the air, so that the buoyancy will remain the same while the power gas is consumed. (*Bulletin of the Daniel Guggenheim Fund for the Promotion of Aeronautics, Inc.*, no. 6, May 22, 1928, 4 pp., *g*)

Flying Dangers and Safety Devices for Aircraft

AN ANALYSIS of French accidents shows that 54 out of 100 are due to errors of judgment, 33 to engine or structural defects, 5 to weather, and 8 to unknown causes. Out of every 100 killed and 100 injured persons, 62 were killed and 63 injured as a result of faulty airmanship. Accidents due to errors of judgment are usually associated with unintentional stalling, and the author considers several devices to obviate this, among which is said to be a remarkable improvement of the Handley Page slot which he is not permitted to describe. These anti-stall devices fall into two classes: one in which the stall is prevented mechanically, and the other (Savage-Bramson) which indicates to the pilot the approach of stall conditions. He deals also with turn indicators and wireless direction finding. Two turn indicators are described in the original paper and discussion—the Reid, which is air-driven, and the Royal Air Force, which is an electrically driven gyroscope. The advantage of the electrical drive is that running at a constant number of revolutions irrespective of the forward speed of the machine, its sensitivity depends upon the rate of turn and nothing else, whereas in the air-driven type the speed of the gyro depends on the forward speed.

The Schilossky-Cook gyroscope is gravity-controlled, and therefore there is no frictional device of any kind to retard indication of the movement made, the movement of the indicator being damped by suitable air dashpots. It is mounted on knife edges, which, being frictionless, permit a small number of revolutions per minute—1200 r.p.m.—to give the required sensitivity. It also depends on a visual presentation, but not on moving contacts. It has an ingenious device of two screens—each containing one red and one green sector—which can be seen by the pilot, the light shining through both the screens at once, so that it is dark when on a straight course. On a turn two similar colors overlap and give the required indication of the turn. (M. L. Bramson in *The Journal of the Royal Aeronautical Society*, vol. 32, no. 208, Apr., 1928, pp. 247–255 and discussion pp. 255–263, *g*)

The Hele-Shaw Beacham Variable-Pitch Propeller

IN THIS case the pitch of the blades is varied by means of a double-acting hydraulic piston operated by the oil pressure from a variable-stroke pump driven by the engine. The stroke of the pump is in turn controlled by a governor also driven by the engine, so that whatever the air conditions may be, the pitch of the propeller sets itself so as to keep the engine running at a constant predetermined speed. However, the speed at which the governor operates can be altered by the pilot within certain limits by means of a small control lever. The pilot control lever alters the force on the governor spring, and consequently adjusts the speed at which the governor operates.

The principle of operation of the variable-pitch propeller is identical with that of the hydraulic steering gear, with the addition that the control is made automatic. An important matter insisted upon by the Air Ministry is provision for any possible failure of the hydraulic system, for instance, if in a war machine the pipes should be shot away. It is claimed that this condition is satisfactorily met in the particular propeller referred to, together with the other two vital conditions of light weight and reliability. It may be added that one of these propellers has been 30 hr. in flight at Farnborough—where it is being tested by the Air Ministry officials—without any suggestion of breakdown.

The weight of the variable-pitch propeller is quite large at present, but it is expected that it will be reduced in later designs. This matter of weight might not be so important on airships. This propeller is made by the Gloster Aircraft Co. and weighs about 180 lb. as against 100 lb. for a fixed propeller of the same size. (Paper before The Royal Aeronautical Society of Great Britain, April 12, by Dr. H. S. Hele-Shaw and P. E. Beacham; abstracted through *Automotive Industries*, vol. 58, no. 19, May 12, 1928, p. 722, *d*)

ELECTRICAL ENGINEERING

Electric Motors with Intermediary Rotors

FOR certain purposes very high-speed motors are desirable. The velocity of an asynchronous motor is strictly limited by the frequency of the alternating current available, and, for example, with a bipolar motor a maximum speed of 3600 r.p.m. may be obtained with a frequency of 60 cycles per second. In Europe where 50 and even 25 cycles are still common, correspondingly lower maximum speeds are only available. Various means

have been resorted to in order to obtain higher frequencies, such as the use of commutator-type alternating-current motors, frequency converters, etc. All of these methods have certain advantages and disadvantages, however, and resort has been made to the use of a motor with an intermediary rotor which permits increasing the speed but at a cost of considerable mechanical complication. The present article describes several types of these motors, one of which can be run at a speed triple that of synchronism, while another can be run at a speed either greater or less than that of synchronism. (H. dePistoye in *La Technique Moderne*, vol. 20, no. 8, p. 286–292, 14 figs., *d*)

ENGINEERING MATERIALS

Rubber Pavements

FOR EXPERIMENTAL and demonstration purposes part of New Bridge Street, Blackfriars, London, some 700 sq. yd., was paved with Gaisman blocks in October, 1926, and at the same time the remainder of the road was paved with wood blocks. The traffic over the street since then is estimated on what is claimed to be good authority to amount to upward of 25,000,000 tons, and is of the most varied character—from a bicycle to a 16-ton steam truck with trailer. In that time not more than 50 out of 10,000 Gaisman blocks have shown signs of wear, the rest of the pavement being in perfect condition, while the wood blocks have already been worn down more than $^1/_2$ in. in thickness and show inequalities in the surface.

Lately part of the road was taken up to lay electric cables for transmission of current for power purposes, and upon the completion of the work the original rubber blocks were relaid. The whole of this work has been done with complete success, leaving a surface which is indistinguishable from the original. This test is said to have demonstrated, among other things, the following:

a That removal and replacement of the paving are of the greatest simplicity.

b That the original laying of the paving was perfect, being uniform, completely waterproof, and rigidly immovable.

c That an enormous traffic on either side of the open holes had not caused any movement whatever of the unsupported edges of the paving.

d That every block removed, of some 150 in all, was in perfect condition, and that traffic had caused no separation of the rubber from the supporting block to which it was attached.

e That the method of laying and the Rubgrip jointing material were adequate for the purpose and showed no kind of weakness.

f That the rubber, after eighteen months exposure to weather of every conceivable British type, was not in any way deteriorated.

g That the wear of the rubber by shock and attrition was sensibly nil.

h That the paving was quite impervious to water, as shown by the fact that the bed was found to be bone-dry when the blocks were removed. (*Rubber Age*, vol. 9, no. 3, May, 1928, pp. 89–90, *eg*)

FUELS AND FIRING

Rationalization of the Coal Industry in the Ruhr

THE present abstract is based on a series of articles which recently appeared in the *Deutsche Bergwerks Zeitung* written by Dr. Hold, a prominent mining executive of Essen, Germany, and deals with the conditions in the Ruhr coal-mining districts within the last few years. Dr. Hold gives statistics showing that while in 1924 only 25 per cent of the output of Ruhr coal was mined by machinery, in 1927 this proportion had been increased to between 85 and 90 per cent. At the same time, partly because of higher wages, the annual cost of machine mining in the Ruhr has increased by nearly 400 per cent, so that the increased output was obtained at too great a cost.

But rationalization includes far more than the increased use of machinery. Increased production may also be effected by improved organization. An excellent example is afforded by details of the reorganization of a large Westphalian mine in which two adjacent collieries were combined and worked from a single shaft. At the same time surface arrangements were improved, with the result that the output per person per shift was increased from 0.99 ton in 1926 to 1.292 tons in February, 1928. One result of combining these two pits was to save 180 shifts per day, and the output per man per shift was increased from 0.99 ton to 1.070 tons. Among other improvements, a new washery was installed with an increased output of 8 per cent, thus adding 200 tons to the daily output of the pits. This increased the output per man per shift from 1.070 to 1.1125 tons. Underground, the amalgamation of the pits resulted in a reduction in the number of miners employed by 20 fillers and 11 locomotive drivers, whereby the output per man per shift was further raised from 1.1125 to 1.140 tons. By reducing the number of working places by 71, a further saving of 96 shifts per day was effected, again raising the output per man per shift from 1.140 to 1.185 tons. On the surface 71 shifts were saved, and the output per man per shift was further raised to 1.240 tons. Lastly, the new washery enabled 140 tons more fuel to be recovered for use in the colliery boilers, thus increasing the salable output and enabling the final figure of 1.292 tons per man per shift to be reached. It should be noted that the above result is not attributable to the "redoubled blow," but is solely due to methods of reorganization.

When, however, the financial side of these changes is examined, the results are disappointing. Notwithstanding the economies effected, these were more than offset by increased working costs, owing largely to advances in the rate of wages and other factors. It is clear, therefore, that the mere attainment of an increased output per man per shift, calculated by dividing total output by the number of men employed, is capable of giving misleading results so far as working costs are concerned. Closer inspection of the problems of rationalization is giving reason to infer that it is possible to push rationalization beyond the economic limit—in other words, that economy may be too expensive. Owing to various causes, the increased adoption of machine mining and other rationalization measures has been found to be accompanied by a rise in other expenses until at length the savings in one direction are swallowed up by increased costs in others. It is possible for pits to be overmechanized. In the opinion of some, the conditions in the Ruhr have already reached this point. It has been stated that since 1924 the increased output of Ruhr coal, amounting to between 100 and 130 per cent, has been accompanied by an increase in working costs of more than 150 per cent, and the margin between costs and selling price is said to be least satisfactory in the most highly mechanized pits. The realization of these facts has apparently already led to a marked decrease in the number of coal-cutting machines employed in the Ruhr coal field. An example has been cited by a writer in the *Deutsche Bergwerks Zeitung* of a pit which in 1914 produced 2000 tons of coal per day with 2106 men and 112 machines, and is now producing the same output with 1666 men and no less than 698 machines. Here the expansion of machine mining seems to have been out of all proportion to the reduction in manual labor. (Editorial in *The Colliery Guardian*, vol. 136, no. 3512, Apr. 20, 1928, pp. 1551–1552, *g*)

Recent Developments in Coal Fuel

THE paper here abstracted covers several aspects of the fuel problem, such as pretreatment, carbonization, and production of domestic fuel. The subject of smoke abatement is touched upon incidentally. In this connection the author recalled the statement of the Samuel Commission (British) to the effect that the labor of over 1,000,000 miners for three days every year is devoted to providing the material for making smoke and thereby polluting the atmosphere. One suggested way to abate smoke is to use gas instead of raw coal. As regards the question of carbonization, it would appear that some processes are already reaching the stage of regular operation on a commercial scale, while others are still experimental. Of the latter, the one at the Fuel Research Station is particularly mentioned. This is an externally heated plant which has not yet entered upon the stage of fully commercial operation, but is near to it. It consists of two—in this case vertical—cast-iron retorts of a very elongated rectangular shape with rounded corners, placed in a setting which consists of a large brick box. The measurements are 6 ft. 3 in. at the top widening to 6 ft. 9 in. at the bottom. It is 21 ft. high, the narrow part being 7 in. at the top and 11 in. at the bottom. These retorts have proved themselves very elastic; the disadvantage of them is that their throughput capacity is not and cannot be very great. One advantage is that a very wide range of coals can be dealt with. Coals have been put through those retorts ranging from highly swelling Durham coals down to coals which do not knit together but which go through the retort in the lump form. At first it was intended to make the plant operate continuously, but it was soon found that though this worked quite well with some coals, it made too much breeze. Then it was tried intermittently, and it was very soon in trouble; a very good coke could be made, but the retort was left in a sort of naked condition between the two charges, at which it reached a dull red heat. The result was overheating, and one setting put up lasted exactly a fortnight. Now the success, if success is claimed in the technical working of that plant, was due to the adoption of a semi-intermittent continuous process in which the coal is dropped a certain distance every now and then—but there is nothing new in that. The proportion of time and space that is worked on is 3 ft. per hr.—it may be dropped exactly 3 ft. every hour or 6 ft. every two hours, and by ringing the changes between those two factors, 3 ft. per hr. and 6 ft. in 2 hr., it has been found possible to work even strongly swelling Durham coals through that retort. It will work with very strong coking coals.

The retorts have stood up for two years, which is not good enough, as they ought to stand up longer. They are still working, but when they were taken down twelve months ago it was found that a bulge had taken place. This is of course a metallurgical problem, and was passed to the Cast Iron Research Association, which is advising the Fuel Research Station.

As regards the solid-fuel production, it is much easier to produce by low-temperature carbonization a fuel in the form of breeze than one in lumps. If fine coal with a sufficient coking power is used it will form lump coke, but may cause difficulty from sticking in many types of retort. The coking power can be regulated by blending. Some coals with medium coking power if charged to the retorts in lumps will come through in lumps. The advent of pulverized-fuel firing may have a considerable bearing on the development of a type of retort that does not easily produce a lump coke.

The author, who has had very close association with the Bergius process, considers next processes which do not claim to produce a marketable solid residue but produce oil. The Bergius process consists in mixing powdered coal with thick oil in the proportions of five to one to form a thick paste, which is forced into bombs in which it is treated with hydrogen at a temperature of some 480 deg. cent. and a pressure of some 200 atmos. In the latest plant the coal passes through three bombs one after the other. A large proportion of the coal substance is liquefied, after which it is cooled, and the pressure released in stages. The gas is scrubbed to recover gasoline. This process is interesting as a possible means of supplying from coal the oil required in Great Britain, but it is still far from having reached a development which is commercially practicable.

A process similar to the Bergius process is being used in Germany by the I.G., who have a plant which makes 60 tons a day of gasoline from lignite and appear to be making a profit. They are carbonizing the lignite and making gasoline by hydrogenating the tars. The coke is used for the production of water gas, which again is used to make hydrogen, partly used for the hydrogenation and partly for synthetic ammonia. There are at the works coke ovens and a nitrogen-fixation plant as well as a hydrogenation plant, and this combination allows all the products to be used to the best advantage.

The author considers as the most immediately interesting result of the work on the hydrogenation of coal, the possibilities opened up as to obtaining information about the actual constitution of the coal substance. In the examination of the Bergius process at the Fuel Research Station some curious phenomena have been observed. It is known that the coking properties of coal can be reduced or destroyed by heating the coal in air, and it has now been found that by hydrogenating the coal the coking properties can be increased. The author showed a piece of coke made from coal with no coking power at all. The coal was put into the bomb as a powder, and if carbonized in the ordinary way would have remained a powder. It was given a comparatively mild treatment with hydrogen and came out of the bomb as a hard, pitch-like material which when carbonized makes a hard and swollen coke. In fact, it gives a hard, compact coke if mixed with two or three times its own weight of the original non-coking coal. This does not mean, however, that such a process can be used for producing a commercial-price coke from a non-coking coal. Water gas may be used instead of hydrogen. (C. H. Lander, D.Sc., in a lecture before the Glasgow Section of the Society of Chemical Industry, Jan. 17, 1928; abstracted through *Chemistry and Industry*, the Journal of the Society of Chemical Industry, vol. 47, no. 14, Apr. 6, 1928, pp. 356–359 and discussion, pp. 359–360, *egp*)

HYDRAULIC ENGINEERING

Maximum Permissible Suction Head on Water Turbines

THE question of what should be the maximum permissible suction head on hydraulic turbines has become acute within recent years. Even in the past care was taken not to use suction heads of 8 to 9 m. (26.24 to 29.52 ft.) as this might bring about trouble in the same way as is the case with pumps where the barometric pressure sets the natural limit to the suction head. When, however, high-speed wheels (Kaplan and propeller turbines) came into use it was found that even in the case of suction heads of 2 to 3 m. (6.56 to 9.84 ft.) which hitherto were considered harmless, trouble occurred, and it became clear that the so-called static suction head (the difference of level between the lower edge of the runner and the tail-water level) was not the true measure of the possible danger. It therefore became necessary to give careful consideration to the dynamic suction head.

The water leaves the runner with a considerable velocity which is the greater the higher the specific number of revolutions n_s. In very rapidly running wheels the energy available in the cross-section of the discharge from the runner may be as

high as 50 per cent of the total available energy. Should this water be permitted to discharge into the tail water the efficiency of the turbine could under no conditions be higher than 50 per cent, apart from the ever-present loss due to the static suction head. By employing a thin diffuser with small curvature and expansion in the direction of the stream, it has become possible to recover the greater share of this discharge energy. This recovery of energy shows under the wheel as a decrease of pressure and as an increase of effective head in the wheel. The expression for the velocity of discharge c_m is usually given as follows:

$$c_m = k_{cm}\sqrt{2gH_0}$$

where H_0 is the total head. The velocity head is $\frac{c_m^2}{2g}$ or $k_{cm}^2 H_0$. The draft tube recovers from this the part $\eta_s k_{cm}^2 H_0$ where η_s is the efficiency of the draft tube and usually of the order of 0.6 to 0.8. The pressure at the discharge from the runner is therefore less by the amount $H_s + \eta_s K_{cm}^2$ than the barometric pressure existing at the discharge from the draft tube. (The barometric pressure is B expressed in meters of water, and H_s is the suction head.)

It is obvious that the pressure below the runner cannot go lower than the average light vapor pressure of the water, which at usual water temperatures is only from 10 to 20 cm. of water, as otherwise the water would begin to boil (cavitation). If this water-vapor pressure be neglected, the expression

$$B - H_s - \eta_s k_{cm}^2 H_0 = 0 \quad \ldots\ldots\ldots\ldots [1]$$

holds approximately good, and from it may be obtained the following expression for the maximum permissible suction head:

$$H_s = H - \eta_s k_{cm}^2 H_0 \quad \ldots\ldots\ldots\ldots\ldots [1a]$$

If η_s is known (and this can be obtained without much difficulty) the solution for each type of turbine may be presumably solved, since k_{cm} is given by the turbine specification.

Actually, however, the thing is not quite so simple. Any designer who would rely on Equation [1a] solely for guidance would be apt to be unpleasantly surprised. As a matter of fact, it has by no means been proved that the pressure immediately

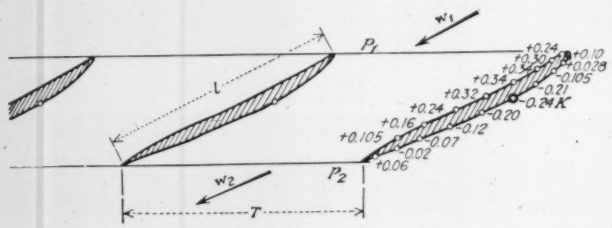


Fig. 1 Blade Sections ("Blade Shutter") of a Propeller Turbine

behind the runner is the lowest occurring anywhere within the turbine. One must not, therefore, rely on the common unidimensional theory of turbines, but must base the design on the forces acting on the individual turbine blades. This is all the more important the fewer the number of blades.

There is no complete theory of the Kaplan runner, but a useful approximation thereto may be obtained by using the conception of a "wing shutter." Assume that the runner is cut by a coaxial cylinder and the cut is developed. This will give something like what is shown in Fig. 1, which differs from the usual blade sections only by the smaller ratio l/T.

It is only necessary to find out whether at any point in these sections the pressure drops particularly low. Under certain conditions a single blade will act as a wing in the aerodynamic sense, and it becomes possible to apply the methods of this science by considering the action of the other wings as minor disturbances. Unfortunately, however, for greater heads, the assumption that l/T is small does not hold good in the case of fast-running turbine wheels, and it is found that l/T is nearly equal or entirely equal to unity. This makes exact computation difficult and tedious, and recourse to experimentation necessary. Such experimentation appears to have been carried out at the Aerodynamic Testing Laboratory at Göttingen, the results of which were published late in 1927. The present article is based on that investigation.

In Fig. 1, on the right-hand side, are given the partial vacuums and gage pressures on various parts of the blade compared with the pressure p_2 behind the blade shutter, as well as the pressure at the beginning of the draft tube. From the values here given it appears at once that the pressure does not uniformly decrease from p_1 or pressure in front of the shutter to p_2 behind the shutter. On the contrary, it appears that p_2 falls much lower than might have been expected on the suction side, and that generally the

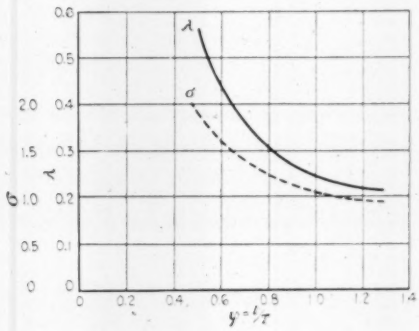


Fig. 2 Values of λ and σ as Functions of Length of Blade

minimum of pressure in the turbine is to be found at K. As in a nozzle, the pressures in the blade shutter vary with the square of the amount of fluid going through. The author refers then to the velocity head of the relative velocity w_2 and writes accordingly

$$\frac{p - p_2}{\gamma} = a\frac{w_2^2}{2g} = a k_{w2}^2 H_0$$

The values a are given in Fig. 1. At point K in particular the pressure is lower than p_2 by the amount $-a_{max}\frac{w_2^2}{2g}$. Assuming that $-a_{max} = \gamma$, one can write

$$0 = B - H_s - \eta_s k_{cm}^2 H_0 - \lambda k_{w2}^2 H_0$$

and from this may be computed the cavitation coefficient

$$\sigma = \frac{B - H_s}{H_0} = \eta_s k_{cm}^2 + k_{w2}^2$$

As a rule engineers are satisfied with a value of σ determined experimentally, and with the present status of our knowledge in this field such a determination is quite justified. It is, however, of interest to note that by using the dimensions of the shutter it is possible to obtain quite a satisfactory value of σ by computation. The author gives an example of how this is done, and adds that D. Thoma of Munich has made a test of a wheel similar to that which he is using for his computation and

found experimentally a value in fairly close agreement with that obtained analytically.

On the whole, the author claims that by a properly selected profile and a proper selection of diameter, and (hence k_{cm}) together with proper selection of shape of blade, a further advance may be made in the degree of utilization of higher heads of water. Finally, however, the turbine designer, just the same as the designer of the ship propeller, reaches the limit where cavitation phenomena step in. In low-specific-speed turbines neglect of λ is not quite so dangerous as in faster turbines. However, in turbines running at high speeds ($\eta_s > 250$) it is no longer permissible to compute the factors leading to cavitation by considering only the static suction head. (J. Ackeret in an article in *Schweizerische Bauzeitung*, vol. 91, no. 11, March 17, 1928, pp. 135-136, 2 figs., *t*)

Cavitation Phenomena in Hydraulic Turbines

CAVITATION has become of importance only recently because of the great increase in speed of hydraulic turbines. It is due to the fundamental property of water which causes it to vaporize even at room temperatures when the pressure is sufficiently low. When such a temperature and pressure are reached bubbles of vapor, and of gas previously dissolved in water, become liberated and interfere with the operation of the turbine; furthermore cavitation leads to pitting of the blades. The purpose of the present article is to show the causes of the low pressures occurring and to localize the critical points in the turbine. To this purpose the author considers a low-head turbine having a draft tube. The partial vacuum at the exit from the wheel, which is the difference between the external barometric pressure B in meters of water and the pressure obtaining at the given point of the turbine, is obviously equal to the height H_s of water in the draft tube. Also, obviously H_s cannot be greater than B, which means that $B > H_s$ must be satisfied. At high altitudes B is lower than at sea level, as shown by a table in the original article, and hence the possible height of suction diminishes with altitude, and for levels of about 1000 meters above sea level H_s will be of the order of 9 to 10 meters. Those, however, who are familiar with the operation of hydraulic turbines know that it would lead to a lot of trouble if such a great suction head were adopted. The condition $B > H_s$ is therefore incomplete, or rather it deals only with static conditions on the assumption that there is no water circulation in the turbine and that the height H_s has merely to satisfy the "law of communicating vessels." Actually, however, this is not so, of course, as the water does circulate in the turbine, and when coming out of the wheel it still possesses a certain amount of kinetic energy. The velocity of water at the exit is constant if the tube is cylindrical, but decreases if it expands, for example, in the shape of a cone; in accordance with the principle of the conservation of energy, when the velocity of water, i.e., its kinetic energy, decreases, there must be an increase of potential energy, and hence of pressure. The author expresses this algebraically, using the following notation.

c_1 = velocity of water at the entrance to the draft tube

$\frac{p_1}{\gamma}$ = pressure prevailing at the entrance to the draft tube measured by the height of water

c_2 = velocity of water at exit from the tube

$\frac{p_2}{\gamma}$ = pressure prevailing at the exit from the tube measured by the height of water

γ = specific weight of water, and

g = acceleration due to gravity in metric units.

The following equation may be used to express the condition of the conservation of energy in accordance with which the sum of the kinetic and potential velocities (neglecting friction) is constant.

$$H_s + \frac{p_1}{\gamma} + \frac{c_1^2}{2g} = \frac{p_2}{\gamma} + \frac{c_2^2}{2g} = \text{constant}$$

On the other hand, the principle of continuity demands that

$$c_1 F_1 = c_2 F_2$$

where F_1 and F_2 are the suctions at entry and exit from the draft tube, F_2, however, being usually several times larger than F_1. As c_2^2 is very small it can be neglected and the above equation written in the form

$$\frac{p_2}{\gamma} - \frac{p_1}{\gamma} = H_s + \frac{c_1^2}{2g}$$

Here $c_1^2/2g$ represents the addition to the partial vacuum caused at the exit from the wheel by the conical shape of the tube, or

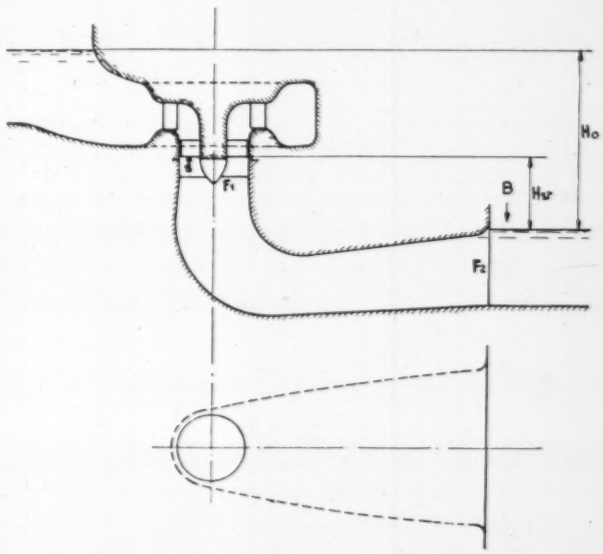


FIG. 3 FRANCIS TURBINE WITH KINETIC EXIT TUBE
(H_0, total head; H_{st}, static suction head; F_1, section at entrance to draft tube; F_2, section at exit from draft tube.)

in other words the dynamic suction height added to the static suction height H_s. In reality this dynamic suction height is less than c_1^2 because of the improved efficiency of the tube, and hence

$$H_{dyn} = \eta \left(\frac{p_2}{\gamma} - \frac{p_1}{\gamma} \right)_{max} = \eta \frac{c_1^2}{2g}$$

The pressure p/γ expressed in terms of height of water prevailing at S, Fig. 1, is therefore

$$\frac{p}{\gamma} = B - H_s - H_{dyn} = B - H_s - \eta \frac{c_1^2}{2g}$$

and since p obviously cannot become zero, we shall have at the limit

$$B - H_s - \eta \frac{c_1^2}{2g} = 0$$

or

$$H_s \leqq B - \eta \frac{c_1^2}{2g}$$

The author considers next as an example a Francis turbine with a spiral casing and the following characteristics:

$H_0 = 200$ m.
$c_1 = 0.20\sqrt{2gH_0} = 12.5$ m. per sec.
$\frac{c_1^2}{2g} = 8.0$ m.
$B = 10$ m.

Assuming that the static suction head is only 3 meters and that the efficiency of the tube $\eta = 0.90$, the dynamic recuperation will be

$$\eta \frac{c_1^2}{2g} = 0.9 \times 8.0 = 7.2 \text{ m.}$$

and the pressure at the exit of the wheel will be

$$\frac{p}{\gamma} = 10 - 3 - 7.2 = -0.2 \text{ m.}$$

which is *negative*. There will therefore be the risk of cavitation, with all the bad features that it implies. This can be helped by reducing H_s to, say, 1 m., or perhaps to 0, as the above calculation has shown that even when there is no static suction there is still a powerful dynamic suction in the tube. Hence the author states as a general rule that it is not sufficient to suppress H_s in order to ward off all possibility of cavitation.

The author next cites the case of the Kaplan turbine and introduces here a ratio denoted by σ which is ratio between H_{dyn} and H_0 (Fig. 3). In this case the permissible magnitude of σ and the danger of cavitation diminish when the blades of the Kaplan turbine are made longer, which brings them nearer the older form of wheels and incidentally eliminates local partial vacua. The original article gives a curve based on experiments and showing σ as a function of the ratio l/T for a turbine of specific speed $n_s = 600$. This curve shows that an elongation of the blades is at first very efficient and then becomes considerably less so. In practice no such very fine adjustments are made, and it is considered sufficient to determine merely the critical value of σ. From another curve given in the original article it would appear that for a value of σ below 0.6 the efficiency becomes very low. (Article by J. Ackeret in *Escher-Wyss Mitteilungen*, no. 2, abstracted through *Bulletin Technique de la Suisse Romande*, vol. 54, no. 9, May 5, 1928, pp. 99–102, 6 figs., *t*)

INTERNAL-COMBUSTION ENGINEERING

Experimental Diesel Engines

ONE of the principal aims of the British Admiralty Engineering Laboratory at West Drayton has been to assist by obtaining experimental data in the development of Diesel engines of high power on the basis of the minimum expenditure of weight and space which is consistent with a speed of revolution suitable for use with the marine propeller. The study centers around the general behavior and characteristics of engines of the following types: 4-stroke-cycle trunk-piston engine, 4-stroke-cycle double-acting engine, 2-stroke-cycle stepped-piston engine, 2-stroke-cycle opposed-piston engine, and 2-stroke-cycle double-acting engine. In each case single-cylinder units have been constructed bearing in mind that as a general rule only the cylinder conditions can be derived from them. In other words, if the mechanical efficiency of the unit cylinder is low, it does not necessarily follow that the low efficiency would be repeated in the actual seagoing engine.

The principal engines with which this paper deals are the "Digit" and the "Datic." The former was built from designs prepared at the Laboratory and is of the simple 4-stroke-cycle type with a trunk piston having a cylinder diameter of 20 in., a stroke of 20 in., and a speed of 390 r.p.m. On a two-hour test it gave an indicated horsepower of 497 and a brake horsepower of 390, of which 48 hp. was compressor horsepower. The Datic engine is a 2-stroke double-acting engine of the high-speed type with a working cylinder of 25 in. bore, a stroke of 22 in., and a normal speed of 320 r.p.m. The scavenge and supercharge air is provided by pumps driven by two of the three throws in the crankshaft, which are provided for the purpose of balancing the masses of the power line which is over the center crank. The extension of the crankshaft is used for driving an air compressor. The designed indicated horsepower of this cylinder was 2000, and this was obtained after extensive experimental work, with the accompaniment of an invisible exhaust. During the series of trials the engine was forced up to its limit, and a maximum of 2300 i.hp. was attained, the exhaust being almost invisible.

The question of power required to drive the blast-air compressor appears to be of considerable importance as regards the question of mechanical efficiency. It increases rapidly with the speed of revolution. To pump 100 cu. ft. of free air per min. to a pressure of 1000 lb. per sq. in. in a practical compressor requires 44 b.hp. at 250 r.p.m., 50 at 320 r.p.m., 63 at 360 r.p.m., and 65 at 400 r.p.m. It is possible to be 50 per cent wrong in the estimate of power required if a low-speed air compressor be used for high-speed work.

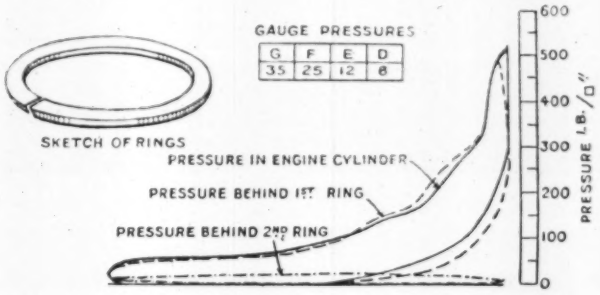
There is another aspect, however, to the question of speeding up such engines or increasing their size or both, and that is the natural falling off in efficiency (apart from mechanical efficiency, pure and simple) due to the general effect of size. The general characteristics of the efficiency curve of these reciprocating engines are shown in a figure in the original article, wherein the curve of efficiency reaches a peak at a certain piston speed and then falls off very rapidly. This is due to the fact that the power required to drive the blowers must increase at an appreciably greater rate than that developed in the main cylinder as the sizes and speeds of revolution increase. It may be unwise, therefore, to assume that because certain high overall efficiencies can be obtained in small engines, they can necessarily be obtained in large sizes, and any comparison between large engines of slow speed or high speed and small engines with high or slow speed, should be made with the greatest care in this respect. Experiments appear to bear this out.

The question naturally arises, therefore, as to whether it is better to have a small number of large cylinders for a given power, or a large number of small cylinders. The engine builders of the Mercantile Navy as a general rule favor the former practice, and the aircraft engineers the latter. As regards durability, the Digit engine was stripped to the bedplate, and the wear of the main working parts was found to be practically nil. The large, heavy engines must, of necessity, have heavy bearers underneath them; the light, fast-running engines would not require this additional weight. One objection to large engines is that even at an establishment like the Laboratory, where there is plenty of floor space, it becomes difficult at times to find room for all the large pistons, rods, liners, cylinder heads, valve gears, etc. whenever it becomes necessary to dismantle the engine—this aspect would require special consideration if such large cylinders were considered for use in the relatively confined spaces of a warship. High compressions have been employed at times in both engines. The effect on the cylinder-liner wear has not been at all marked. But if the combustion conditions are not reasonably good, the Laboratory experiences show that wear which can only be described as most excessive, may be encountered.

Figures in the original article of which only one, Fig. 4, is here reproduced, show the magnitude of the gas pressures that may

attain behind the piston rings, thereby causing heavy pressure between the ring and the liner. Many attempts to cure this have been tried and the investigation is still being pursued. In Navy practice the number of piston rings ranges from about five to six as a rule, and an experiment based on the above-mentioned tests showed that it may not be wise to reduce the number provided unduly, as this tends to prevent the escape of heat from the piston to the water jacket and may result in piston seizure.

Experiments show that where there is an unbalanced side pressure on the piston it is imperative that the scavenge and supercharge air in the air duct be concentrated in a large volume in close proximity to the air ports in order to avoid the air having to travel unnecessary distances in the brief period available for the scavenging process. A figure in the original article shows what might be called right and wrong arrangements of the scavenge and supercharge air pipes and reservoirs. Among other things, it is pointed out that there is always a present need for all parts subjected to heat to be as symmetrical in form as possible.



CYLINDER LINER BOTTOM JOINT TEST AND PISTON RING EXPERIMENTS

FIG. 4 CYLINDER-LINER BOTTOM-JOINT TEST AND PISTON-RING EXPERIMENTS

As regards the injection of fuel, no material advance has been made on the methods described in the previous papers, the bulk of the work having tended toward the attainment of better scavenging of the cylinders at high speeds. The general effects of bad scavenging are fourfold. First, the retention of a proportion of foul air in the fresh-air charge under compression tends to retard the rate of ignition of the fuel as it enters the cylinder—causing after-burning during the expansion stroke. Secondly, this after-burning of the fuel during the expansion stroke which, in addition to being bad from a thermodynamic aspect, causes the release pressure when the exhaust valve is opened, or port uncovered, as the case may be, to be higher than intended, while at the same time the exhaust temperature is also higher than it need be. Thirdly, the higher pressure and temperature at release causes more delay in the rate at which the gases escape from the cylinder, so that by the time the air valve opens, or the ports are uncovered, the internal cylinder pressure may not have expanded down to a pressure sufficiently low in order to avoid interference with the ingress of fresh air from the scavenge pump. Fourthly, this delay of the ingress of fresh air interferes with the scavenging process by raising the pressure necessary to force it into the cylinder, with the result that the compression charge is not only a mixture of fresh air and foul, but is unduly heated as well. Under these conditions, which appear to come upon the engine with some suddenness—the collapse of the engine's performance being rather abrupt—the wear of the cylinder liner may be excessive.

The paper next discusses some features on the subject of scavenging and makes a brief general comparison between the four-stroke and the two-stroke engines. This part cannot be abstracted because of lack of space.

In the discussion which followed, Engineer Commander H. B. Tostevin said that the two outstanding facts referred to in the paper were the development of over 2000 hp. in the single cylinder of the Datic engine, and the achievement of mean indicated pressures exceeding 200 lb. per sq. in. in the case of the Digit engine. These results undoubtedly placed the Laboratory in the forefront of progress in Diesel-engine experiments. It was stated in the paper that the highest mean indicated pressure obtained in the Digit engine, without supercharging, was 159.6 lb. per sq. in. In such a case only a definite air charge was possible, and only a certain amount of fuel could be burned. To obtain higher powers it was therefore essential to supercharge, but it was clear that the additional power required for the supercharger must be obtained from the exhaust, and not from the independent units, to obtain the greatest advantage.

Prof. C. J. Hawkes thought that it might be as well to point out that the Digit engine was designed for a very specific purpose, that of investigating high mean pressures, while the Datic engine was designed more with a view to general information. In considering the design of the latter engine, it was felt that special attention be given to factors governing combustion, and the shape of the combustion chamber had been designed with this point in view. On the whole, the results given in the paper might be regarded as reasonably good, but the scavenging appeared very inefficient. The scavenge trunk should, of course, have been alongside the engine instead of being connected by pipes. He noticed that in the Datic engine the scavenge and supercharge air pressures were the same throughout. The original idea had been to keep the two systems entirely separate, and he would like to ask the author whether it was not considered worth while to do this. (Engr. Capt. A. Turner, R.N., in a paper before the Institution of Naval Architects, March 29, 1928, London; abstracted through *Engineering*, vol. 125, nos. 3247–3248, Apr. 6 and 13, 1928, pp. 425–427, 462–464, 12 figs., and discussion in *Engineering*, Apr. 6, pp. 407–408, *eA*)

7000-B.Hp. Sulzer Marine Diesel Engine

THIS is one of four engines ordered for fast single-screw motor cargo boats for service between Holland and the East Indies by the Netherland Steamship Company. The vessels are to be 490 ft. long between perpendiculars, and of 17,450 tons displacement. Among the distinguishing features of the present engine is the method of scavenging and charging through a double row of ports in the cylinder liner, the upper ports communicating with the scavenge-air receiver being fitted with automatic valves. The scavenge air is admitted through these ports when the exhaust pressure has a value below that of the air in the receiver. On the compression stroke the air ports remain open for a short period after the exhaust ports are covered, a slight supercharge being thus effected. The cylinder head is perfectly symmetrical, with only one opening in the center for the combined fuel and starting valve.

The engine has eight cylinders with the injection-air compressors carried on the same bedplate. The cylinder bore is 2 ft. $8^{9}/_{32}$ in., and the piston stroke is 4 ft. $8^{11}/_{16}$ in. The engine actually develops 7040 b.hp. at 100 r.p.m. The pistons are water-cooled by jet injection which has been recently developed for Sulzer engines and takes the place of the older telescopic-pipe arrangement. The water is projected from the mouthpiece in the form of a jet, which is directed into a divergent nozzle at the bottom of the moving pipe. The usual central jet pipe, which occasionally got out of line and led to rapid wear, is thus omitted. A modification of the arrangement previously described has been made in the engine under discussion. The upper sliding pipe is ball-mounted in the piston, and passes through scraper rings where it enters the lower fixed pipe.

These rings serve to throw off surplus oil from the outside of the pipe on the descent of the latter, while on the ascent, any water which is projected past the outside of the divergent nozzle at the base of the moving pipe is scraped off by the rings. This water does not fall back into the main jet pipe, but is directed into an annular space between this pipe and an outer pipe concentric with it. From the bottom of this space, it is taken to a separate outlet in the observation box mounted on the side of the crankcase. This box also contains the orifices through which water falling back directly from the jet passes, and it was noticeable, on test, that only a small volume of water is returned in this way, while that scraped off the outside of the pipe by the rings was at most a mere dribble and has often entirely ceased. (*Engineering*, vol. 125, no. 3247, Apr. 6, 1928, pp. 412–413, 4 figs., *d*)

The Lead Tetraethyl Inquiry Committee

AN INTERDEPARTMENTAL Committee has been appointed in Great Britain to inquire into the dangers to health arising from lead tetraethyl in gasoline, with representatives of the Ministry of Health Home Office—which corresponds to the Department of the Interior here, the Air Service War Department, and the Department of Scientific and Industrial Research. The committee is inquiring into the possible dangers to health resulting from the use of gasoline containing lead tetraethyl or similar lead-containing compounds, and is to report what precautions if any are desirable in connection with the use or handling of such gasoline. (*The Chemical Age*, vol. 18, no. 458, Apr. 7, 1928, p. 322, *g*)

LUBRICATION

An Experimental Determination of the Distribution and Thickness of the Oil Film in a Flooded Cylindrical Bearing

THE mathematical theory of lubrication as set forth by Osborne Reynolds and extended by Sommerfeld is now very widely recognized, but owing to lack of data when the theory was first set forth, it is now considered that some of the assumed conditions are not altogether justified. This paper is an account of recent experiments made with the object of supplying such data.

The vertical lift, the horizontal shift, and the frictional resistance have been determined for a slack-fitting bearing under widely different conditions of load, speed, and temperature for three oils of different viscosity. It is found that the vertical lift and horizontal shift are greatest when the load and temperature are low and the viscosity and speed are high.

The vertical lift is about 0.02 in. at its maximum, and falls to about 0.0001 in. just before seizing occurs. The horizontal shift varies in much the same manner. By combining the two movements the exact position or "attitude" of the bearing relative to the shaft can be obtained, also the "eccentricity" of the bearing, but the experimental results are not altogether in accordance with the theory. The reason for the discrepancy is a matter of considerable interest.

From the "attitude" and "eccentricity" of the bearing the mean thickness of the oil film can be calculated, which, together with the speed and viscosity of the oil, provides the necessary data for calculating the frictional resistance. Such calculation gives results agreeing well with experiments at a certain viscosity of the oil, but there is a discrepancy when the viscosity is reduced.

Emphasis is laid on the effect of the exact fit of the bearing on the shaft either due to wear or to the rigidity of the housing. The bearing was found to wear even when running at loads much below the seizing point, an explanation of which is found in the fact that when the shaft is at rest it embeds itself into the bearing along a narrow strip at the crown, and when running, something approaching metallic contact occurs along this strip so long as the vertical lift is less than the depth of the indentation.

The investigation has involved the making of extremely delicate measurements under difficult conditions which prevent a high degree of accuracy from being attained. It is believed that by cross-plotting in no case does the error exceed 10 per cent, and in general it is probably not greater than 5 per cent. The results are therefore claimed to be a good first approximation, and justify publication because there are no other published data on the subject. (John Goodman, in Paper No. 4681, not yet completely printed, but reported here from *Sessional Notices of the Institution of Civil Engineers*, no. 3, March, 1928, pp. 79–80, *e*)

MACHINE PARTS

The Rieseler Hydromechanical Reduction Gear

THROUGH an error in the abstract describing this device and published in MECHANICAL ENGINEERING, June, 1928, p. 476, one of the illustrations was omitted, namely, Fig. 1 of the original

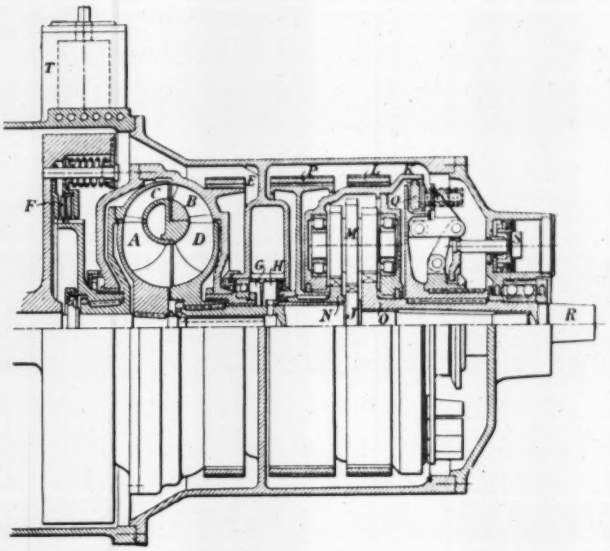


FIG. 5 LONGITUDINAL SECTION OF RIESELER HYDROMECHANICAL REDUCTION GEAR

article. This is reproduced here as Fig. 5. (*Engineering*, vol. 125, no. 3248, Apr. 13, 1928, pp. 444–445, 10 figs., *d*)

Flexible Pipe Joints in a Quarry

THE installation was made at the slate quarry at Berwyn, North Wales, and consists of 300 yd. of 3-in. pipe line fitted with "victaulic" joints running up a mountain side and carrying air at 80 to 100 lb. per sq. in. pressure from a high-speed steam-driven vertical air compressor.

The standard design of the victaulic joint is essentially a heavy ring of rubber composition bent over into the form of a flat inverted U and contained in an outer metal housing ring made now nearly always of steel alloy. The pipes are made with a small shoulder or rim at each end. The encircling metal ring is bolted around in such a manner that the lips of the rubber ring press down evenly all around the flat surface of the two shoulders or rings, and the

greater the pressure the tighter becomes the joint without interfering with the flexibility. (*The Quarry and Surveyors' and Contractors' Journal*, vol. 32, no. 374, Apr., 1928, pp. 137–138, *d*)

MARINE ENGINEERING (See Internal-Combustion Engineering: 7000-B.Hp. Sulzer Marine Diesel Engine)

POWER-PLANT ENGINEERING

Methods for Plastic Furnace Lining

THIS is largely a practical article giving details of procedure, and much of it is therefore not of a suitable nature for abstracting.

A few fundamentals to be followed with monolithic furnace lining are the following: Secure a quality grade of plastic, use a sufficient quantity of it, pound it firmly into place, shave the exposed surfaces, and dry properly either by air or by means of a low fire.

One manufacturer has developed step-by-step directions for installing a plastic furnace in order that maximum results may be obtained with the least expenditure and with the least labor. Although these directions are given by one company with particular reference to their product, they are sufficiently general to be adhered to in the use of practically any high-grade plastic refractory material. It will be noted that these directions apply particularly to horizontal return tubular boilers, but with readily apparent changes the correct application of plastic lining to other types of furnaces can be made by any one familiar with boiler practice.

Another most important point of installation overlooked by many is the necessity for having all furnace walls supported substantially. When good supports are not available, anchors should be used to provide adequate wall support. One anchor for every 30 in. square is the most practical ratio for good results.

When the furnace wall is longer than 10 ft., it should be built into sections by means of expansion joints. The latter are simply thin boards built into the walls, and they are burned away when the regular fire is started under the boiler. The joints left by these boards' burning out may be filled with asbestos, but that is really unnecessary.

The ease with which the plastic lining can be molded has led some to run the material solid around the corners. This should not be done, but each wall should be built separately. In fact, it has been found excellent practice to install the furnace linings in such sections that the parts subjected to the hardest usage can be replaced without tearing out the entire lining. This treatment is particularly advantageous when powdered coal and similar fuels are used, with certain areas receiving the full force of the heat and flame. Replacing small areas now and then is quite a saving in both time and money for repairs, besides permitting maximum furnace performance at all times.

The above, however, represents only a small part of the article. (J. L. Cummings, Mgr., Refractory Dept., S. Obermayer Co., in *Southern Power Journal*, vol. 46, no. 5, May, 1928, pp. 48–53, 14 figs., *p*)

Operating Experiences with High-Pressure and High-Temperature Steam

THE author surveys and lists the stations using what might be considered today high-pressure steam, which means anything from 400 up to 2800 lb. From this it would appear that high-pressure steam is being used quite extensively both in this country and in Europe. On the whole, he finds that there seems to be no difficulty in handling high-pressure steam with apparatus of the conventional type made proportionately heavy, and that many of the troubles which were expected never developed.

However, unexpected troubles of various kinds have developed, and have been overcome in the same way as when in earlier days similar troubles were corrected in boilers working under ordinary pressures. Handhole-gasket troubles have been reported from a number of sources. This sort of trouble has always been with us and is soon eliminated. Feed-pump troubles have developed in most every plant and have been corrected, but not as easily as the gasket trouble. Feedwater regulators have given some trouble, but were soon put right. Gage-glass troubles have been reported from nearly all plants. These troubles have ceased when heavier and better-designed fittings have been provided. Some trouble has been experienced from the leaking of cast-steel fittings, but this can be as easily overcome as when 200 lb. pressure was the standard.

A number of operators have reported that finely powdered solids have been carried over with the steam into the turbine, where it has made the usual trouble by deposition in nozzles and erosion of blades. Just how this material is carried is not known, but when the concentration of the boiler water is reduced to the proper point, this difficulty should disappear.

What is more, even high superheat temperatures have not given the trouble that they were expected to. At the Langerbrugge (Belgium) station the standard superheat temperature is 850 deg. fahr., and there does not seem to be any more trouble than is common in the low-pressure stations.

Without exception all operators agree that the installation of the high pressure they use has been justified by results, thermal and commercial, and a number are installing more machinery of the same kind. These repeat orders have been given in base-load plants, in bleeder or high-pressure plants exhausting into process or low-pressure mains, where the turbine acts as a reducing valve, and also in stations without base load as at Langerbrugge and Charlottenburg. It would thus appear that in these conditions the extra first cost of the high-pressure apparatus was not very large, and, quite possibly, of the order suggested in the author's 1922 paper.

Turbines and piping and valves used for high pressure have not departed materially in design from the lower-pressure standards. Where higher temperatures than the usual 700 deg. to 750 deg. fahr. are concerned, the expansion problem must be more carefully considered. Very probably up to 800 to 850 deg. fahr. the usual qualities of steel will perform satisfactorily, but some operators report the use of alloy steels for shells, tubes, and castings. Riveted drums have not been used above 650 lb. except at Langerbrugge, where some trouble has occurred from leaks. All of the remainder of the high-pressure jobs use forged or welded drums, or else no drums at all. Such boilers as the Benson and Atmos only require collectors, while in the Hartmann and Loeffler boilers the drum is away from the fire and the heating is internal through the agency of superheated steam. (Geo. A. Orrok, Mem. A.S.M.E., in a paper presented at the Mid-West Power Conference; abstracted through *Combustion*, vol. 18, no. 5, May, 1928, p. 308–310, *pc.A*)

Removing Molten Ash by the Hydro-Jet System

THIS system has been installed in connection with the pulverized-fuel-burning boilers at the Charles R. Huntley Station of the Buffalo General Electric Company. The handling of molten ash proved to be a troublesome problem, and while the new furnaces were in the process of construction, experiments were made of dropping the slag directly from the furnace into a concrete buggy filled with water. No explosion

occurred, and there was little sputtering. The slag stream proceeded to form its own insulating tube to the bottom of the buggy, and built up as if there were no water on top of it. The sheet-metal casing on the bottom of the buggy became red hot long before the surface of the water showed any signs of boiling. When the bucket was half-full of slag it was rolled to one side, and some fifteen minutes later it was emptied and the interior of the slag was still red hot.

Sluicing was then tried out by placing an 8-ft. length of 12-in. channel iron, sloped at an angle of about 30 deg., under the spout of the original boiler and placing two $^3/_4$-in. water nozzles at the top so as to sweep the channel clean. The lower end discharged into an ash car.

These tests on sluicing led to observations that were of great value in arriving at the final solution. The slag stream was broken into small pieces by the mechanical force of the jets, and these pieces in turn tended to shatter into smaller pieces, owing to the rapid chilling effect of the water made possible by the exposing of greater surface areas per unit volume of slag. These facts indicated the necessity of using comparatively large volumes of water and were responsible for hydro-jet handling.

A test equipment was then installed under one boiler by the Allen-Sherman-Hoff Company. This consisted of three primary jets which threw parallel streams forming, owing to close spacing, a water table within a cast-iron disintegrating chamber. On this the molten slag fell directly, being broken into small pieces and partly chilled at this point. Falling from here into a U-shaped cast-iron trough, the slag was carried crosswise to the building with the aid of two carrier jets for a distance of approximately ten feet, and was still further chilled in the process, owing to additional cold water. This flow hit a cast-iron smashing plate, where it was turned at right angles into another U-shaped cast-iron trough running lengthwise 50 ft. in the adjoining yard. Two additional carrier nozzles working in tandem were placed at the head end of this run.

The result from this test equipment exceeded expectations. The slag was deposited in a fine granular state at the discharge of the chute.

In the permanent installation the sluice is discharged into a pit. Two special manganese-steel pumps, each of approximately 760 g.p.m. capacity, were provided for this service, and a cast-iron suction pipe run into the discharge pit. All elbows in the suction and discharge piping are of manganese steel. One pump is intended for a spare, as both are connected in parallel to the same discharge main, which is of 6-in. steel pipe running along the side of the building and out across the adjacent land to the point of disposal. The pipe is pitched to make it self-draining and is not insulated. The material discharged spreads over a wide area instead of forming a pile beneath the pipe as was expected.

In operation the system has worked out as satisfactorily as on test, although it has been found desirable to increase the pressure at the nozzles from 100 to 140 lb. in order to handle a higher rate of slag flow. These rates of flow are uncertain, being dependent upon the length of time the boiler is in service, the furnace temperature, and the prior day's firing condition and length of service. (Donald H. Scranton, Engineer with the Buffalo General Electric Co., in *Power*, vol. 67, no. 18, May 1, 1927, pp. 754–757, 7 figs., *d*)

PUMPS

The "Electromersible" Pump

AMONG the present demands for specialized electrical machinery for meeting exceptional requirements are motors of the immersible type for combining with centrifugal pumps. If is often desirable to place the pump and motor in a position in which it may frequently get submerged, or it is sometimes more convenient to lower the pump and motor right into the water so as to obviate priming, foot valves, or a long suction pipe.

For this special work a recent design of machine is the "Electromersible" pump made by J. Samuel White & Co., Ltd., under license in accordance with the patents of T. L. Reed-Cooper; this type of pump is said to have been adopted by the British Admiralty, and is in use for auxiliary services on H.M.S.'s *Nelson* and *Rodney*. In these cases the pumps have to comply with exacting conditions of size and weight, for output. The output per pump is specified at 100 tons per hr. against a 75-ft. head, or against any head down to free delivery on deck without overloading the motor; and it must operate equally well above water as when submerged 40 ft., and under all conditions without any adjustment. On tests the pumps proved capable of giving a continuous output of 125 tons per hr. against 75 ft., the motor factor was 0.91, and on the continuous full-load test run the temperature rise did not exceed 55 deg. fahr.

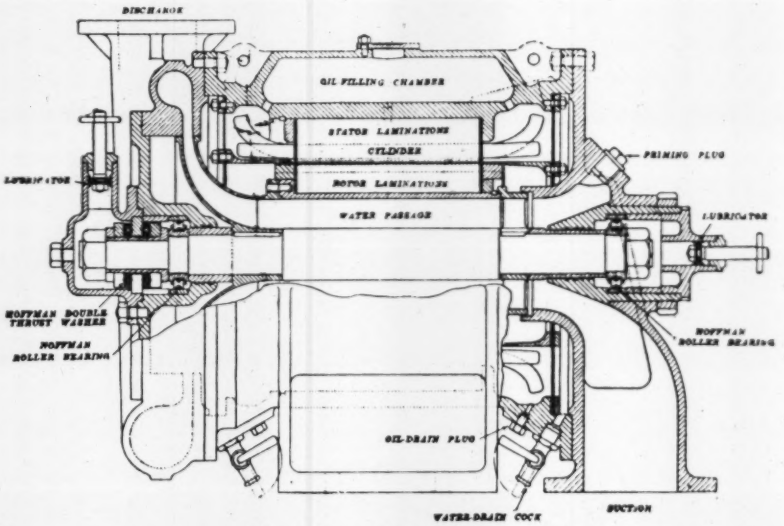


FIG. 6 THE "ELECTROMERSIBLE" PUMP

The machine consists of a three-phase squirrel-cage motor combined with a centrifugal pump, the rotor of which runs in the water. The stator core and windings are protected with a water-tight non-corrodible enclosure which is filled with transformer oil; the oil forms a good cooling medium, and also prevents condensation of atmospheric moisture in the winding enclosure. As shown in Fig. 6, the water enters the suction at one end of the motor and passes along through an annular space in the rotor which is joined to the impeller. The shaft therefore runs freely between the two end bearings without requiring any glands, and the leakage water around the periphery of the impeller fills up the space around the stator-winding enclosure and is drawn into the suction again at the running clearance of the rotor at the opposite end, thereby forming a very efficient cooling circulation when the motor is working above water. The oil- and water-tight enclosure is of a special alloy, and is entirely stationary. The stator laminations are thus protected

from corrosion and the windings are suitably cotton-covered, insulated, and varnished to suit oil immersion.

The water is led in by means of screw vanes at the intake end, whereby a rotary motion with pressure is gradually imparted to it, thus reducing the shock in meeting the impeller blades. The revolving element, consisting of the shaft, impeller, rotor, bearings and housings, can be easily removed, without breaking the points of the suction and delivery connections to the pump casing, by unbolting the cover at the impeller end and unscrewing the nut on the bearing housing at the suction end, so that the working parts of the pump can be easily and quickly examined and dried out after use, if desired. The outer casing of the machine is so designed that it forms a completely air-tight enclosure. (*The Electrical Review*, vol. 102, no. 2627, Mar. 30, 1928, p. 572, *d*)

RAILROAD ENGINEERING

Ljungström Turbine Locomotives

IN ADDITION to those in Sweden there is at least one locomotive in England and another in Argentina, and the present article gives some data of tests on these locomotives. The one in Argentina is of particular interest as it showed on test the fuel consumption for a piston-engine locomotive to be at least 50 per cent higher than for a turbine locomotive, this figure being based on operation extending over about 100,000 km. (62,137 miles). (*Revue Générale des Chemins de Fer*, vol. 47, no. 4, Apr., 1928, pp. 312–314, 4 tables, 1 fig., *g*)

RUBBER RESEARCH (See Research: British Rubber Research)

RESEARCH

British Rubber Research

THE Rubber Industries Bill which has been lately before the British Parliament contains, among other things, a provision for promoting rubber research. It is not yet clear whether this will include research on synthetic rubber, and in this connection the following information may be of interest.

To return to the matter of research in rubber technology, there is much to be done in spite of many notable advances which have been recorded in recent years. The use of reclaimed rubber is increasing, particularly in America, and especially when raw rubber advances markedly in price. Thus in 1926, when raw rubber reached about four shillings ($1.00) a pound during one period, almost half as much reclaimed rubber as new raw rubber was used in America. In 1922, when low prices ruled for rubber, the proportion was under 20 per cent. Reclaimed rubber, although greatly improved in quality and ease and cheapness of production, is still far behind new raw rubber in many essential properties, but its use effects economies in material and working charges. A thorough understanding of the devulcanization process and other factors will stimulate interest in reclaimed rubber.

Much still remains to be done in the matter of accelerators for rubber vulcanization, for their mode of action is imperfectly understood, and their influence in rendering compounded rubber more durable and resistant to the deteriorating influences of aging may lead to much. Their use is almost general, and it is noteworthy that the simple acceleration of the vulcanization process is not the only reason for their popularity. Anti-oxidants of themselves have been developed, but again their function and applicability merit close study in view of the suggestive results already achieved.

Chemical engineering problems exist in the rubber industry, and such potentially valuable processes as the anodic deposition of rubber from natural or artificial latices still present many problems. The transportation and use of rubber latex, spray drying and vulcanization, the use of rubber latex in paper making, the production of thermoplastics imitating gutta percha and shellac from rubber by means of organic sulphonic acids, the making of chemical and acid-resisting apparatus and tanks, and of resistant paints, the cold vulcanization of rubber and the application of rubber in many new fields, are matters which have been noted frequently in the technical press, and they are sufficient to justify the belief that the program of rubber research will not lack interest. (Editorial in *Chemistry and Industry*, Journal of the Society of Chemical Industry, vol. 47, no. 14, Apr. 6, 1928, pp. 353–354, *g*)

Research Statistics

THE latest available information shows that we now have in the United States upward of 1000 industrial research laboratories with well over 10,000 trained research workers aided by a small army of assistants, mechanicians, glassblowers, helpers, etc. No accurate statistics are available giving the annual expenditure in this country for industrial research, but this runs into many millions of dollars and a number of individual laboratories have budgets of a million or more dollars a year. These are very impressive figures, and themselves definitely answer the question as to whether research is of value to present-day manufacturers.

As a rule, the principal function of the industrial research laboratory is to develop new and useful products and processes for the industry it serves. It some cases its main function may be, in cooperation with customers, to develop new uses for products already developed. It may be established for the main purpose of improving manufacturing processes or aiding the development of new devices and applications based on some outstanding invention which provides the main product of the manufacturers served. Most industrial research laboratories find that an inevitable part of their work consists in curing and anticipating troubles either with the product, the processes involved, or the application of the product. (C. E. Skinner, Asst. Director of Engineering, Westinghouse Elec. & Mfg. Co., in a paper before the Annual Meeting of the American Gear Manufacturers' Association, Apr. 19–21, 1928; abstracted through *Machinery*, vol. 34, no. 9, May, 1928, p. 707, *sg*)

SPECIAL MACHINERY

Ball Bearings in a Jib Crane and Trolley

IT IS CLAIMED that ball bearings serve a useful purpose in such applications when the crane must be swung around many times a day. A design is shown in which the weight of the entire assembly and the load produced by the carrying beam are taken up by a large double-row ball bearing mounted at the bottom in such a way that it takes all of the end-thrust load as well as resisting a large share of the radially applied load. The upper part of the supporting member is provided with a single-row ball bearing having a floating outer race. It is claimed that in an application of this kind ball bearings will last longer than the machine to which they are fitted, because the speed of rotation is very low and no lubricating difficulties are experienced. It is also claimed that ball bearings make it easier to swing the crane. (New Departure Manufacturing Co. in *Western Machinery World*, vol. 19, no. 3, March, 1928, p. 125, 1 fig., *d*)

Permanent-Mold Casting by Vacuum

THE process here described imitates for metals that used for making glass bottles by machine. A piece of pipe is held

vertically in the molten metal and a vacuum applied. This fills the pipe with metal to a height regulated by the amount of vacuum. To prevent the metal from easily discharging from the pipe the latter is provided with a constricted opening dipping into the metal. The process is now successfully used in a machine with 12 mold-carrying arms for making lead battery grids. The machine can produce 3000 battery grids per hour if a single mold is used. A smaller machine is being designed by the Vacuum Castings Co., Toledo, Ohio, which manufactures the machines. The present developments have been primarily with white metals, but castings have been produced also from aluminum alloys. (Edwin Bremer in *The Foundry*, vol. 56, no. 7, Apr. 1, 1928, pp. 256–259, illustrated, *dl*)

TESTING AND MEASUREMENTS

Testing Soil Pressure, Resistance, Friction, Etc.

THE author has previously installed at the Testing Plant of Foundation and Hydraulic Construction at the Technical Institute in Hanover a unit for testing the behavior of various soils, dry and wet, under pressure, their resistance to stresses, friction, etc. This installation was, however, comparatively small, and while larger than the usual laboratory testing plant, did not permit testing to be carried out on a sufficiently large scale. The case in which the tests were carried out was 1 m. × 5 m. (3.28 ft. × 16.4 ft.) in horizontal section and 1.40 m. (4.6 ft.) high.

The new installation described here is equipped with a soil container 7 m. (19.68 ft.) long and 2 m. (6.56 ft.) high and wide. It is closed on all four sides and provided with a bottom. The walls are made of plate 10 mm. (0.39 in.) thick, and strongly reinforced. The container is put together with closely spaced countersunk rivets, the joints being such that wet materials can be tested. The dimensions of the container can be assumed from the fact that it can take 28 cu. m. of soil (988 cu. ft.) with a weight of about 50 tons. The arrangement of the "pressure wall" is shown in Fig. 7. The forwardly loaded pressure wall is movably located with respect to the rear frame wall and is supported on six roller trains. This forward-pressure wall consists of a system of steel U-beams and a wooden wall formed on these beams. The rear part of the beams is used to help the rails for the roller trains. The wooden wall has a number of circular orifices which are 200 mm. (7.8 in.) in diameter and which have pressure nozzles set in them to measure the local pressures.

The upper part of the wooden wall support is strongly reinforced and projects sideways over the container wall. It also carries rollers by which the wall is suspended in the container, as well as devises for measuring the vertical forces.

The rear pressure wall is likewise very strongly built. The whole pressure wall may be driven forward by a device which permits effecting a pressure as high as 100 tons. The device is driven by an electric motor working through a worm and worm gear.

The installation here described is a development of several previous installations made on an increasingly large scale. In the former installations it was found that the best way to measure the various phenomena here occurring was probably by measuring all the forces as pulls. This proved to be more exact than measuring them as pressures. All the forces to be measured are divided into horizontal and vertical forces. The horizontal forces are measured by four dynamometers holding the driving mechanism in the soil container (left lower end of Fig. 7). Two of these dynamometers are of the self-registering type. While the driving mechanism has a capacity of 100 tons, each of the four dynamometers is limited to 10 tons, giving a total maximum horizontal force capable of measuring only 40 tons. In none of the tests carried out hitherto has this maximum been exceeded, but of course, more powerful dynamometers would be required should greater stresses be anticipated. The vertical frictional forces are measured along the front movable pressure wall provided with a counterweight on one hand and a dynamometer on the other hand. (See Fig. 7 at right.) These dynamometers are attached at the upper end to the carrying frame of the movable wall and at the lower end to the rollers, held on a lower guide rail but capable of forward motion together with the wall. This lower roller is mounted on ball bearings, and by the use of a wire drive is made to move at the same forward velocity as a pressure wall. This device measures the effect of a wedge of soil forced out when soil pressure occurs at a rock wall, and provision is made for the measurement of soil pressures on a smooth wall as it is.

Vertically upward-directed forces occur when the wall displacement is upward relatively to the soil wedge. These forces

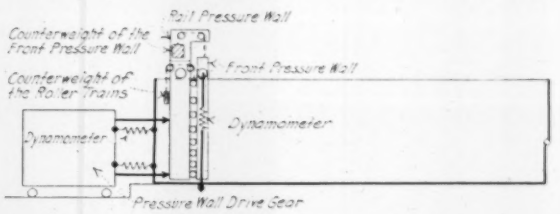


FIG. 7 PRESSURE-WALL ARRANGEMENT IN THE LARGE UNIT FOR TESTING SOIL PRESSURES AT THE HANOVER TECHNICAL INSTITUTE

can be produced by increasing the counterbalanced load with the loose wall. The two dynamometers used to measure the vertical forces have each a capacity of 10,000 kg., which is the same as the four dynamometers for measuring horizontal forces, and likewise would have to be replaced by more powerful units under certain conditions of test. Measuring devices are provided to determine the distribution of pressure on the pressure wall and side walls.

The author mentions briefly some tests which have been carried out with this installation. Among others a certain method of construction was suggested in connection with the building of the Hamburg subways. It was desired to find out whether the suggested method was practical, particularly as the work had to be done especially well because the subway at this point intersected with a surface line and the latter was not to be affected in any way. It was therefore desired to determine whether the available ground volume was capable of resisting the active soil pressure of the surface railroad line, and what would be the available factor of safety. The tests were carried out on model structure with the small container and the large one. In the case of the small container the dimensions of the model compared to those of the actual structure were as 1 to 7, and in the large container as 1 to 2.38, which means that in the case of the large container a very substantial approach to a full-size test was made. The tests, which are not described in detail, are said to have given a complete answer to the problems in question. (Prof. O. Franzius in *Der Bauingenieur*, vol. 9, 1928, nos. 7 and 8, 4 pp. 5 figs., *d*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Code on Instruments and Apparatus

Preliminary Draft of Part 2, Pressure Measurement, Chapter 6—Tables, Multipliers, and Standards for Barometers, Mercury and Water Columns, and Pressure Measurements

The Main Committee on Power Test Codes takes pleasure in presenting to the members of the Society for criticism and comment, Chapter 6 of Part 2 of the Code on Instruments and Apparatus, dealing with Tables, Multipliers, and Standards for Barometers, Mercury and Water Columns, and Pressure Measurements. The Individual Committee which developed this draft consists of Messrs. C. F. Hirshfeld, Chairman, W. A. Carter, Secretary, C. M. Allen, E. G. Bailey, L. J. Briggs, C. R. Cary, J. D. Davis, R. E. Dillon, F. M. Farmer, J. B. Grumbein, W. H. Kenerson, E. S. Lee, O. Monnett, S. A. Moss, R. J. S. Pigott, and E. B. Ricketts.

Code No. 19 on Instruments and Apparatus will consist of twenty-two parts dealing with the following subjects: (1) General Considerations,[1] (2) Pressure Measurement (6 chapters),[2] (3) Temperature Measurement (11 chapters),[3] (4) Head Measurement, (5) Measurement of Quantity of Material, (6) Electrical Measurements, (7) Mechanical Power, (8) Measurements of Indicated Horsepower, (9) Heat of Combustion, (10) Chemical Composition, (11) Quality of Steam, (12) Time Measurements, (13) Speed Measurements, (14) Mechanical Measurements, (15) Surface Area, (16) Density, (17) Viscosity Measurements, (18) Humidity, (19) Concentration of Dilute Solutions, (20) Smoke, (21) Leakage Measurements (2 chapters),[4] and (22) Hydraulic Power Plants.

The Individual Committee, the Main Committee, and the Society will welcome suggestions for corrections or additions to this draft from those who are especially interested in this subject. These comments should be addressed to the Chairman of the Committee in care of The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y.

General Remarks on Mercury-Column Corrections

1 The following tables for the correction of barometers and similar mercury columns, give corrections to 0.01 in., which is sufficiently accurate for usual engineering purposes.

2 There may be used instead of the tables contained herein, one of the following tables which give corrections to 0.001 in. and from which the tables herein have been abridged.

Barometers and Measurements of Atmospheric Pressure. Circular F, U. S. Weather Bureau. Sold by Supt. of Documents, Washington, D. C. Price 15 cents. (Contains most convenient tables and information on barometers.)

Smithsonian Meteorological Tables, 4th Edition reprint 1924, Publication 2493, Smithsonian Institution, Washington, D. C. Price $2.

Smithsonian Physical Tables, 7th Edition reprint 1927, Publication 2539, Smithsonian Institution, Washington, D. C. Price $3.

3 Proper discretion as to the degree of accuracy required must be used in taking and correcting readings of barometers and mercury columns.

4 For some cases, precision greater than 0.01 in. is required, as for example, in steam-turbine tests involving small final pressures, in which case the readings and corrections must be accurate to 0.001 in. of mercury column. In other cases less precision is required, as for example when the barometer is used only for the computation of the absolute pressures above atmospheric, and then readings and corrections need be only somewhat more accurate than the pressure gage used.

Standard Conditions for Mercury Columns

5 The standard temperature to which the readings of barometers and mercury columns are to be reduced is 32 deg. fahr.

6 Reduction to conditions of standard gravity is also assumed, although in nearly all engineering work the gravity correction is so small as to be negligible. These standards are adopted for the reason that they are customary in most physical and scientific work, and are used in reports of barometric pressure by the U. S. Weather Bureau.

Standard Barometric Pressure for Condensers, Engines, and Turbines

7 The vacuum or back pressure above atmospheric given in a contract, specification, or otherwise noted as the value for which an apparatus is designed, is called the *Rated Vacuum* or *Rated Back Pressure*. This implies also a "Standard Barometric Pressure" which may or may not be given. When the rated vacuum, back pressure, or the "Standard Barometric Pressure" is expressed in inches of mercury, such as "28 in. vacuum" or "28 in. vacuum with 29.92 in. barometer" or "28 in. with 30 in. barometer," it is to be understood that the figures are readings of the mercury columns after reduction to 32 deg. fahr. (standard temperature).

8 When a test is being run, the actual barometric pressure must be found and corrected to 32 deg. fahr. The difference between this value and the Standard Barometric Pressure gives a correction which must be applied to the Rated Vacuum or Back Pressure. This, then, gives a value which should be approached as nearly as possible by the actual vacuum or back pressure (corrected to 32 deg.) which is held during a test. Any difference calls for a correction of the results of the test. In terms of absolute pressure, the given standard prescribes that the actual absolute pressure is the difference between the reading of a mercury gage corrected to 32 deg. fahr. and the barometric pressure as it would be reported by the Weather Bureau for the actual elevation. This is to be equal to the rated absolute pressure, which is the difference between the rated vacuum or back pressure and the standard barometric pressure.

9 If a rated vacuum or back pressure is given, the standard atmospheric pressure of 29.92 in. of mercury column at 32 deg. fahr. is understood to be at sea level or a value interpolated from Table 4 for the actual altitude, unless otherwise specified.

Barometric Temperature Standard

10 A standard barometric pressure which occasionally has been used is one corresponding to some average room temperature, such as 60 or 70 deg. fahr. In such a case the absolute pressure is determined by subtracting the reading of a mercury vacuum gage from the reading of the barometer, without correction for temperature in either case when such temperatures are near the standard temperature. This standard requires the use of a value for the barometric pressure different from that used by the Weather Bureau, does not take account of the

[1] This part was published in the February, 1923, issue of Mechanical Engineering.

[2] Chapter 1 of Part 2, on Barometers, was published in the November, 1927, issue of Mechanical Engineering.

[3] Chapter 1 of Part 3, General, was published in the December, 1925, issue of Mechanical Engineering.

Chapter 6 of Part 3, Glass Thermometers, was published in the April and May, 1926, issues of Mechanical Engineering.

[4] This part was published in the November, 1925, issue of Mechanical Engineering.

possibility that the barometer and mercury gage may be in different rooms, and lacks precision.

11 Another standard barometric pressure, which has been described in some textbooks and steam charts, is based upon the assumption that when the term "30 in. barometer" is used the standard atmospheric pressure of 29.92 in. of mercury column at 32 deg. fahr. is meant. Accordingly, on this basis the given value of 30 in. is understood to be 30 in. at some particular condition of temperature, which when corrected to 32 deg. fahr., will give 29.92 in. of mercury column. This temperature has been worked out and found to be about 58 deg. fahr., and systems have therefore been used in which all mercury-column heights have been reduced to values corresponding to a temperature of about 58 deg. fahr. In this reduction of the value of 30 in. to standard conditions, the gravity correction has been omitted. For a gravity correction such as that which would correspond to 40 deg. north latitude (a representative mean for the U. S.), the temperature at which an actual 30-in. column must be in order to correspond to 29.92 in. of mercury column at standard conditions is about 53 deg. fahr. The use of any such standard is objectionable for the reason that it requires reduction of the mercury-column measurements to values corresponding to a temperature different from that temperature used in physical and scientific work, and also because it requires the use of a corrected barometric pressure varying from the value used by the Weather Bureau.

12 In all of the standards above mentioned, the readings of the mercury gage and of the barometric column are both to be corrected to the same temperature basis. Hence the expression of the absolute pressure in inches of mercury, according to any of the standards indicated above, differs from the expression of any one of the other standards merely by a difference in the temperature corrections applied to the readings of usually short mercury columns. The differences are such as would be given by absolute-pressure gages at the different standard temperatures of 32, 53, 60, or 70 deg. fahr. These differences are often very slight, and are negligible for most engineering purposes. That is to say, while the different standards give appreciable differences in the corrected readings of the mercury gage and the barometer, there is very little variation in the difference between the two which measures a small absolute pressure. Hence steam tables and steam charts using the 32-deg. fahr. or the 58-deg. fahr. standard for absolute pressures in inches of mercury, may be used interchangeably with negligible error, so long as small absolute pressures are adhered to, and so long as the temperature corrections in both the barometer and the mercury gage giving the vacuum are made according to the same standard.

13 A given absolute pressure expressed by a height in inches of mercury at the standard here used of 32 deg. fahr. is 0.26 of 1 per cent less than the height in inches of mercury at 58.1 deg. fahr.

14 For some engineering work and where extreme precision is not required, the readings of mercury and water columns in rooms where temperatures range from 60 to 80 deg. fahr. may be used sometimes without correction, if reduction multipliers corresponding to average room temperatures are used as specified in lines 3, 4, 5, and 7 of Table 6. Such readings must be marked "Not corrected for temperature" or be otherwise designated, and it must be understood that they do not conform to any standard.

15 In exceptional cases the barometer reading may be used in the same way, but it must then be marked "Uncorrected Barometric Pressure."

Temperature Corrections for Barometers and Mercury Columns up to 32 In.

16 Table 1 is used in correcting the readings of a barometer, mercury gage, or mercury U-tube of any kind. The correction given reduces the reading to the value which would be obtained if the mercury column were at the standard temperature of 32 deg. fahr. The table also includes a slight correction for the temperature expansion of a brass scale, which is taken as being correct at 62 deg. fahr. The scale temperature correction is usually negligible for engineering purposes.

17 The table gives the amount to be added to or subtracted from the observed reading in inches of mercury column.

TABLE 1 TEMPERATURE CORRECTIONS FOR BAROMETERS AND MERCURY COLUMNS UP TO 32 IN.

Temp. of column, deg. fahr.	Observed Reading of Column in Inches of Mercury: 16	18	20	22	24	26	28	30	32
	ADD								
−20	0.07	0.08	0.09	0.10	0.11	0.11	0.12	0.13	0.14
−10	0.06	0.06	0.07	0.08	0.08	0.09	0.10	0.11	0.11
0	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.08	0.08
10	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.05	0.05
20	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	SUBTRACT								
35	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
40	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03
45	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05
50	0.03	0.03	0.04	0.04	0.05	0.05	0.05	0.06	0.06
55	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.08
60	0.05	0.05	0.06	0.06	0.07	0.07	0.08	0.08	0.09
65	0.05	0.06	0.07	0.07	0.08	0.09	0.09	0.10	0.10
70	0.06	0.07	0.07	0.08	0.09	0.10	0.10	0.11	0.12
75	0.07	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.13
80	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15
85	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16
90	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.17	0.18
95	0.10	0.11	0.12	0.13	0.14	0.16	0.17	0.18	0.19
100	0.10	0.12	0.13	0.14	0.15	0.17	0.18	0.19	0.20

Temperature-Correction Formula for Any Mercury Column

18 For mercury columns with lengths not given in Table 1 the height corrected to the standard temperature of 32 deg. fahr. may be found to a close approximation[5] by subtracting from p in inches at temperature t deg. fahr., a correction determined from the following formula: Deduction for temperature $= p \times (t - 32)/10{,}000$. This formula assumes that the measuring scale is correct at its actual temperature.

Corrections for Barometers and Pressure Gages for Decrease of Atmospheric Pressure with Elevation

19 For exact work, a gage reading must be corrected by means of Table 2 to take account of the weight of the column of air between the level of the center line of the apparatus in test or other reference plane and the level of the place where atmospheric pressure acts upon the gage. The correction is found by multiplying the value given in Table 2

TABLE 2 CORRECTIONS FOR BAROMETERS AND PRESSURE GAGES IN INCHES OF MERCURY FOR DECREASE OF ATMOSPHERIC PRESSURE PER 100 FT. INCREASE IN ELEVATION

Mean altitude, in feet	Mean Atmospheric Temperature, Deg. Fahr.: −20	0	20	40	60	80	100
0	0.13	0.12	0.12	0.11	0.11	0.10	0.10
1000	0.12	0.12	0.11	0.11	0.10	0.10	0.10
2000	0.12	0.11	0.11	0.10	0.10	0.10	0.09
3000	0.11	0.11	0.10	0.10	0.10	0.09	0.09
4000	0.11	0.10	0.10	0.10	0.09	0.08	0.08
5000	0.10	0.10	0.10	0.09	0.09	0.08	0.08
6000	0.10	0.10	0.09	0.09	0.08	0.08	0.08
7000	0.10	0.09	0.09	0.09	0.08	0.08	0.08

by the difference in elevation in feet, divided by 100. The correction is applied to the gage reading as follows: For a gage reading below atmosphere, set at a low elevation: subtract. For a gage reading below atmosphere, set at a high elevation: add. For a gage reading above atmosphere, set at a low ele-

[5] The maximum error is of the order of 0.01 in. An example in which $p = 30$ in. and $t = 100$ deg. fahr. gives a correction of 0.20 in. by the formula, while the correction from Table 1 is 0.19 in.

vation: add. For a gage reading above atmosphere, set at a high elevation: subtract.

20 An independent correction (discussed in Chapter 3 of this Part) must be made to take account of the weight of any column which may be in the pressure pipe, between the level of the center line of the apparatus in test and the level where the column in the pressure pipe acts upon the gage if pressure pipe is wholly filled; or on the basis of actual height of column if pressure pipe is partially filled.

21 The corrections mentioned automatically take account of the exceedingly slight effect of the buoyancy of the atmosphere on the weight of a water or mercury column. This is on the basis that the weight of unit volume of water or mercury has had the exceedingly slight correction for air buoyancy theoretically supposed to be made in exact weighing.

Correction of Barometers and Mercury Columns to Standard Gravity

22 The gravity correction, given in Table 3, need not be made for most engineering purposes. However, Weather Bureau barometric heights always include a gravity correction, and hence the slight corrections should be made in any barometer reading taken for purposes of accurate calibration by comparison with a Weather Bureau reading. The table gives the amount in inches of mercury to be added to or subtracted from the observed reading. The gravity correction reduces the reading to the value which would occur if gravity had the International Standard value of 32.1740 ft. per sec. per sec.

TABLE 3 CORRECTION OF BAROMETERS AND MERCURY COLUMNS TO STANDARD GRAVITY

North latitude, degrees	0	0	2000	2000	4000	4000	6000	6000	8000	8000	10,000	10,000
	Elevation, ft.											
	Height of Column, Inches of Mercury											
	30	28	28	26	26	24	24	22	22	20	20	18
25	−0.05	−0.05	−0.05	−0.05	−0.05	−0.05	−0.06	−0.05	−0.06	−0.05	−0.05	−0.05
30	−0.04	−0.04	−0.04	−0.04	−0.05	−0.04	−0.05	−0.04	−0.05	−0.04	−0.05	−0.04
35	−0.03	−0.03	−0.03	−0.03	−0.03	−0.03	−0.04	−0.03	−0.04	−0.03	−0.04	−0.03
40	−0.02	−0.01	−0.02	−0.02	−0.02	−0.02	−0.03	−0.02	−0.03	−0.03	−0.03	−0.03
45	−0.00	−0.00	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01	−0.02	−0.02	−0.02	−0.02
50	+0.01	+0.01	+0.01	+0.01	−0.00	−0.00	−0.00	−0.00	−0.01	−0.01	−0.01	−0.01

Average Atmospheric Pressures at Various Altitudes

23 Data from Table 4 are to be used for computation of pressures above atmospheric only when no barometer reading is possible. The table, of course, gives only a rough average pressure for average temperatures. The values have been calculated from data given in Table 5 of Report 147, entitled "Standard Atmosphere," W. R. Gregg, 8th Annual Report of the National Advisory Committee for Aeronautics, 1922.

TABLE 4 AVERAGE ATMOSPHERIC PRESSURES AT VARIOUS ALTITUDES

Altitude, above sea level, ft.	Average atmospheric pressure. In. of mercury at 32 deg. fahr.	Lb. per sq. in.	Altitude above sea level, ft.	Average atmospheric pressure. In. of mercury at 32 deg. fahr.	Lb. per sq. in.
0	29.92	14.70	8,000	22.23	10.92
1,000	28.85	14.17	9,000	21.39	10.51
2,000	27.82	13.67	10,000	20.58	10.11
3,000	26.82	13.17	12,000	19.03	9.35
4,000	25.84	12.69	14,000	17.57	8.63
5,000	24.90	12.23	16,000	16.21	7.96
6,000	23.98	11.78	18,000	14.93	7.33
7,000	23.09	11.34	20,000	13.74	6.75

Corrections for Head and Water Columns

24 When a "head" is expressed in feet of water, it is understood to be at the same conditions of temperature and aeration as exist at the apparatus in test.

25 For very precise work the mean of temperatures at inlet and exit of the apparatus in test is to be used. Values of d, the density of water in lb. per cu. ft., for various temperatures with average amount of dissolved air, are given in Table 5. For precise work this must be used. For ordinary work the variation of density with temperature need not be taken into account, and the density is to be taken as that corresponding to the usual room temperature. The corresponding multipliers, to the degree of accuracy needed for usual engineering work, are given in the last column of Table 6.

Density of Water and Multipliers for Water Columns

26 When great precision is required the actual readings of the distance in inches between the levels of water on the two sides of a water gage or U-tube are to be multiplied by the multipliers given in Table 5 to reduce the readings as specified.

Multipliers for Converting Readings of Barometers, and Mercury and Water U-Tubes and Gages

27 These multipliers are given in Table 6; d is the density of water at actual temperature in lb. per cu. ft., as given in Table 5.

Mercury-Meniscus or Capillarity Corrections

28 These corrections are given in Table 7. The correction is in inches and is to be added to the reading of a mercury column comprising a single leg and a reservoir of appreciable area. The table can be used also for a mercury U-tube with legs of different diameters. The reading is to be taken at the top of the meniscus. This table is not to be used with barometers, where the meniscus correction is allowed for in the setting of the scale.

TABLE 5 DENSITY OF WATER AND MULTIPLIERS FOR WATER COLUMNS

Temp., deg. fahr.	Density of water, lb. per cu. ft. d	Multipliers for reducing readings in inches of water column to: Lb. per sq. in. ($d/1728$)	In. mercury at 32 deg. fahr. ($0.001178d$)
32	62.42	0.03614	0.07354
35	62.42	0.03614	0.07354
40	62.42	0.03614	0.07354
45	62.42	0.03614	0.07354
50	62.41	0.03613	0.07352
55	62.39	0.03611	0.07350
60	62.37	0.03609	0.07348
65	62.34	0.03607	0.07344
70	62.31	0.03606	0.07341
75	62.28	0.03604	0.07337
80	62.23	0.03601	0.07331
85	62.18	0.03598	0.07325
90	62.13	0.03595	0.07320
95	62.08	0.03592	0.07314
100	62.02	0.03589	0.07306

Formulas for Pressure Equivalents of Velocity Heads

29 Under certain circumstances prescribed in the codes, the pressure equivalent of the velocity head, as given below, may be added to the observed "Static Pressure" to obtain the "Total" Pressure. This method is alternative to the direct measurement of total pressure by means of an impact tube, as described in Part 2, Chapter 2.

30 The average velocity V must first be found from a knowledge of A and the quantity q flowing, or from the weight w flowing and the actual density d, by means of one of the following formulas:

TABLE 6 MULTIPLIERS FOR CONVERTING READINGS OF BAROMETERS AND MERCURY AND WATER U-TUBES AND GAGES

	Instrument	Reading	Remarks	Multipliers for reducing readings to ft. of water: Lb. per sq. in.	In. mercury	(See Par. 25)
1	Barometer Mercury gage Mercury U-tube	Inches mercury corrected to 32 deg. fahr.	Correction made by Table 1 or Par. 18	0.4912	1.00	$70.74/d$, exactly 1.134 for water at usual room temperature
2	Mercury gage Mercury U-tube	Inches mercury at t deg. fahr.	Use actual reading at actual temperature t deg.	$0.4912 \times \left[1.0 - \frac{(t-32)}{10{,}000}\right]$	$1.0 - \frac{(t-32)}{10{,}000}$ for inches mercury at 32 deg. fahr.	$\frac{74.70}{d}\left[1.0 - \frac{(t-32)}{10{,}000}\right]$
3	Mercury gage Mercury U-tube Barometer (in exceptional cases)	Inches mercury at usual room temperatures	Use uncorrected reading. Results are accurate for temp. of 56 deg. and closely approximate for usual room temperatures	0.49		1.132 for water and mercury at usual room temperatures
4	Mercury U-tube reading hydraulic pressure above atmosphere	Inches between levels of mercury in the two legs. Usual room temperatures	Water on top of lower column only, completely filling the pressure pipe. The result is the pressure at the base of a column of water extending to the level of the zero of the mercury tube. See Chapter 2, Par. 39	$0.49 - \frac{0.036}{2} = 0.472$	1.00 − 0.037 for inches mercury at usual room temperatures	1.090 for water and mercury at usual room temperatures
5	Differential mercury U-tube reading difference between two hydraulic pressures both above atmosphere	Inches between levels of mercury in the two legs. Usual room temperatures	Water on top of both columns completely filling both pressure pipes	0.49 − 0.036 = 0.454	1.00 − 0.74 for inches mercury at usual room temperatures	1.048 for water and mercury at usual room temperatures
6	Water U-tube or water gage	Inches water at t deg. fahr.	Work requiring a precision gage and precise computations. See values in Table 5	$\frac{d}{1728}$	$0.001178\,d$	1/12 for same temp. of gage and column
7	Water U-tube or water gage	Inches water at usual temperatures	For usual engineering work	0.036	0.074 for inches mercury at usual room temperatures	1/12
8	Bourdon pressure gage	Lb. per sq. in.	Reading to be corrected per the gage calibration	1.00	2.036 for inches mercury at 32 deg. fahr. 2.04 for inches mercury at usual room temperatures	$144/d$, exactly 2.31 for water at usual room temperatures

TABLE 7 MERCURY-MENISCUS OR CAPILLARITY CORRECTIONS

Internal diam. of tube in inches	Height of meniscus in inches: 0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08
	Correction in inches to be added							
0.15	0.024	0.047	0.069	0.092	0.116	...	...	...
0.20	0.011	0.022	0.033	0.045	0.059	0.078	...	...
0.25	0.006	0.012	0.019	0.020	0.037	0.047	0.059	...
0.30	0.004	0.008	0.013	0.018	0.023	0.029	0.035	0.042
0.35	...	0.005	0.008	0.012	0.015	0.018	0.022	0.026
0.40	...	0.004	0.006	0.008	0.010	0.012	0.014	0.016
0.45	...	...	0.003	0.005	0.007	0.008	0.010	0.012
0.50	...	...	0.002	0.004	0.005	0.006	0.006	0.007
0.55	...	...	0.001	0.002	0.003	0.004	0.005	0.005

$$v = \frac{q}{60A} \quad \text{or} \quad v = \frac{w}{3600Ad}$$

where V = average velocity, ft. per sec.
A = area of conduit, sq. ft.
q = quantity flowing, cu. ft. per min.
w = quantity flowing, lb. per hr.
d = density, lb. per cu. ft.

31 Having V, the pressure equivalent of the velocity is found by means of the following formulas. The velocity head must of course be expressed in the same units as the static pressure to which it is added. When the velocity head is but a few per cent of the static pressure, the velocity is said to be "low" and the approximate formulas below may be used.

Velocity head in feet of any fluid of the existing density $= V^2/2g = V^2/64.34$.

Velocity head in lb. per sq. in. for liquid or low-velocity steam, air, or gas with actual density d lb. per cu. ft. $= \frac{dV^2}{144 \times 2g} = \frac{dV^2}{9265}$.

Velocity head in inches of water for low-velocity air at usual atmospheric conditions $= (V/66.2)^2$.

32 For high-velocity steam, air, or gas the above formulas are approximate on account of the compressibility of the fluid. The exact total pressure p_2 is determined from the static pressure p_1 as follows:

For steam, the kinetic energy E in B.t.u. per lb. represented by the velocity head may be determined from the formula:

$$E = V^2/2gJ = V^2/50{,}060$$

Then a Mollier diagram or steam table must be used to find p_2. This is the pressure which corresponds to an available energy or heat content which is greater by the amount E than the value corresponding to p_1. Adiabatic change or constant entropy is to be assumed.

33 For high-velocity air or gas:

$$\text{Velocity head} = p_1 \left\{ \frac{1}{\left[1 - \frac{V^2}{2gJc_pT_2}\right]^{k/(k-1)}} \right\} - 1$$

where $J = 778$
cp = specific heat at constant pressure
k = ratio of specific heats at constant pressure and constant volume
T_2 = absolute fahrenheit temperature shown by thermometer or other instrument inserted in the stream. (It is to be noted that such measurement gives the "Impact Temperature" which is the temperature which would exist if the fluid were brought to rest, with or without shock)
p_1 = static pressure.

This is in the same units as p_1. The formula is found by equating the kinetic energy due to the velocity head to the energy corresponding to adiabatic change of a perfect gas from p_1 to the total pressure.

COMPUTATION OF TOTAL PRESSURE

34 The "Total Pressure" is to be found by adding to the "Static Pressure" the velocity head as computed by one of the above formulas, using of course the same units.

35 In case of a vacuum, the velocity head may be added to the "Absolute Static Pressure" to obtain "Absolute Total Pressure," or the velocity head may be subtracted from the vacuum (difference between absolute pressure and barometer) to obtain the "Total" or "Net Vacuum."

CASES WHEN TOTAL PRESSURE IS TO BE USED

36 It is proper to use total pressure, computed as described herewith or measured directly by an impact tube as given in Chapter 2 of this Part, instead of the simple static pressure, to obtain overall performance, efficiency, etc. in the following events: the velocity must be uniform as with centrifugal apparatus; and not pulsating as with reciprocating apparatus; the velocity head must count as energy put into the apparatus, as in the case of the inlet of a centrifugal pump or blower, or it must have been produced at the expense of energy put into the apparatus, as in the case of the discharge of a centrifugal pump or blower.

37 It is to be noted that if velocity or area and density are the same in inlet and discharge pipes, either static pressure or total pressure in both cases may be used.

38 It is to be noted that the barometric pressure gives the "total inlet pressure" in case of a machine taking fluid directly from the atmosphere. In case there is an inlet pipe or conduit, the absolute static pressure within it, plus the velocity head, is equal to the barometric pressure (except for inlet and friction losses, and difference of level with a liquid).

Maximum Allowable Unit Working Stresses for Fusion-Welded Joints[1]

THE question as to what unit working stresses should be allowed for fusion-welded joints of pressure vesssels has been under consideration for several years. Par. U-68 of the Code for Unfired Pressure Vessels specifies 5600 lb. per sq. in. for the limits of size and working pressure of vessels named therein. In specifying the working stress of 5600 lb. per sq. in. for fusion-welded joints, the Boiler Code Committee leaned toward the side of safety with the idea of broadening out the rules as the art advanced rather than to reach out too far at the start with the risk of accidents. There is a feeling on the part of many that a higher working stress should be used with certain types of joints, and that there should be different types of joints and some way of differentiating between different qualities of fusion welding.

A comprehensive series of tests of welded pressure vessels was carried out by the American Bureau of Welding about five years ago with a view to assisting the Boiler Code Committee in its study of this problem. The data obtained from those tests were of material benefit in establishing desired information, but certain types were not included in those investigations and further studies were found to be necessary in order to codify the practice of fusion welding so that not only good results in joining metals will be insured, but also a rating of stress may be assigned to any welded joint, depending upon its soundness and dependability.

The Committee is now in position to announce that studies under way in cooperation with the American Welding Society give promise of the early development of a welding procedure suitable for embodiment in a code that will, if followed, insure safe pressure vessels, and that in addition there has been submitted to it a proposed method of evaluating the welded joint on the basis of tests made of representative specimens thereof. With a view to obtaining discussion and constructive suggestions thereon, the latter method is herewith submitted for the information of every one interested, as follows:

It has been proposed to interrelate in a suitable formula the ultimate strength and the elongation obtained by free and unrestricted bend of sample test specimens of the welded joint. This formula which attempts to give due credit to the ductility factor in the welded joint is as follows:

$$S = \frac{T}{7.15}\sqrt{\frac{E}{10}}$$

where S = maximum allowable working fiber stress, lb. per sq. in.
T = ultimate tensile strength, lb. per sq. in.
E = elongation, in per cent, shown by test specimen subjected to free and unrestricted bending.[2]

The stress determined by the formula should be the maximum stress allowed in the structure. Particular attention should be paid to conditions where this maximum stress may be actually greater than often considered, as in lap or corner joint, if it is desired to apply the formula.

The above formula is based on the general agreement by engineers engaged in the design and fabrication of general steel construction, that a certain amount of ductility is necessary for the safety of any structure subjected to unknown stresses. There is no definite knowledge of the exact amount of ductility needed for any particular case, but information is of course available that certain structures built of material having a certain definite ductility, have proven safe, whereas structures built of materials of low ductility have not shown as consistent results. In ordinary construction work the factor of safety, which has generally been taken as 5, has been based on the fact that there is a certain amount of elongation.

The applicability of this formula is based to a large extent on the newly devised method of determining the ductility of metals by the free and unrestricted bend-test method that substitutes, for the usual methods of bending a specimen around a pin or forcing it between two anvil blocks, the more accurate plan of placing a kinked specimen between the jaws of a vise or in a testing machine so that it will bend freely to a U shape. This method, which gives consistent results, produces an elongation in the outside fibers of the specimen that can be measured directly with a flexible scale, and eliminates the uncertainties of measurement of the bend angle which was formerly used as the criterion. With this method any gage length may be used, but one which takes in the width of the weld appears to be most logical for this purpose as it gives a direct measure of the elongation in, and therefore the ductility of, the weld metal.

Inasmuch as it is the purpose in rating welded joints to obtain

[1] These formulas are published for public criticism at the suggestion of the A.S.M.E. Boiler Code Committee.

[2] See paper by A. B. Kinzel read at the September, 1927, meeting of the American Welding Society, at Detroit, Michigan; also paper by W. B. Miller, read at the same meeting.

a measure of the ductility of the weld metal proper, both the tensile and bend tests, as made for this determination, are applied to specimens with the weld reinforcement ground off. In the application of this formula there is no need to be concerned with what may be accomplished in strengthening a weld by reinforcement, as if a welded specimen with no reinforcement breaks outside of the weld, it will be obvious that the weld is stronger than the plate. The ductility of the welds will vary with the welding rod and the process, but it seems reasonable that if two welds, made by different processes or with different rods, have the same tensile strength and ductility, they should be allowed the same working fiber stress.

In developing the above formula the ductility factor was so incorporated that a lower working fiber stress will be allowed where the material has low ductility, and the working fiber stress will depend directly upon the tensile strength. Using varying values for the factors T and E in the formula, tables of proposed maximum allowable working fiber stresses in pounds per square inch of plate section for welded steel pressure vessels have been prepared. The first table represents the manner in which the formula was first worked out to determine its practicability of application to ordinary working conditions, but Table 2 shows the form in which the calculations will probably be most convenient for ordinary use.

The factor of safety in the last column of Table 1 is the same for any given percentage of elongation. The ultimate strength is either that of the weld metal if the weld breaks during the test, or of the base metal if the fracture occurs in it, and obviously a structure cannot be designed, as far as tensile strength is concerned, except on the strength of the weakest part. It is easily worked out that a factor of safety of 5 is reached at an elongation of somewhat over 29 per cent.

TABLE 1 PROPOSED MAXIMUM ALLOWABLE WORKING FIBER STRESSES IN LB. PER SQ. IN. OF PLATE SECTION FOR WELDED STEEL PRESSURE VESSELS

Per cent elongation by bend test	Ultimate strength in 1000 lb. per sq. in. 45	50	55	60	65	70	75	Factor of safety
5	5,000	5,800	6,100	6,700	7,200	7,800	8,300	9
7½	5,800	6,400	7,000	7,700	8,300	8,900	9,600	7.8
10	6,300	7,000	7,700	8,400	9,100	9,800	10,500	7.15
12½	6,800	7,600	8,300	9,000	9,800	10,500	11,300	6.65
15	7,200	8,000	8,800	9,600	10,400	11,100	12,000	6.25
17½	7,600	8,400	9,300	10,100	11,000	11,700	12,700	5.9
20	8,000	8,800	9,700	10,600	11,400	12,300	13,200	5.7
22½	8,300	9,200	10,100	11,000	11,800	12,800	13,700	5.5
25	8,600	9,500	10,500	11,400	12,400	13,200	14,200	5.3

TABLE 2

Per cent elongation by bend test	Ultimate strength in 1000 lb. per sq. in. Over 45 up to 50	Over 50 up to 55	Over 55 up to 60	Over 60 up to 65	Over 65 up to 70	Over 70 up to 75	Over 75
5 to 7½	5,400	6,000	6,500	7,200	7,700	8,300	8,900
Over 7½ to 10	6,000	6,700	7,300	8,000	8,700	9,300	10,000
Over 10 to 12½	6,500	7,300	8,000	8,700	9,400	10,100	10,900
Over 12½ to 15	7,000	7,800	8,500	9,300	10,100	10,800	11,600
Over 15 to 17½	7,400	8,200	9,000	9,800	10,700	11,400	12,300
Over 17½ to 20	7,800	8,600	9,500	10,300	11,200	12,000	12,900
Over 20 to 22½	8,200	9,100	9,900	10,800	11,600	12,500	13,400
Over 22½ to 25	8,500	9,400	10,300	11,200	12,100	13,000	13,900

It will be observed that the part of the formula covering the factor of elongation decreases the allowable working fiber stress more rapidly than the elongation decreases, and on the other hand increases the fiber stress more slowly than the elongation. This seems quite logical, because there must be a point beyond which an increase in elongation increases the value of the metal but slightly, and because as the brittleness increases, the metal becomes less reliable in service.

For the purpose of applying this formula or the above tables to a specific tank in order that the welds therein may be rated as to allowable working stress, it is proposed that the tensile and bend-test specimens be prepared from samples of plate that are identical with the material to be used in the pressure vessel under consideration, and welded with the same filler rod and type of joint as are to be therein used. The sample of the plate is then to be cut into strips 2 or 2½ in. wide, extending at right angles to the welded joint, so that the weld metal in the joint can be subjected to either the tensile or the bend test. The tensile and bend tests shall be recorded in the manufacturer's data report form under items 8 and 9 covering joints. These figures of the ultimate strength in pounds and the elongation in per cent, when applied to the table, give directly the allowable unit working stress on the vessel in which the joint is used.

Revisions and Addenda to Boiler Construction Code

IT IS THE policy of the Boiler Code Committee to receive and consider as promptly as possible any desired revision of the Rules and its Codes. Any suggestions for revisions or modifications that are approved by the Committee will be recommended for addenda to the Code, to be included later on in the proper place in the Code.

During the past two years the Boiler Code Committee has received and acted upon a number of suggested revisions which have been approved for publication as addenda to the Code. These are published below, with the corresponding paragraph numbers to identify their locations in the various sections of the Code, and are submitted for criticisms and comment thereon from any one interested therein. Discussions should be mailed to the Secretary of the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be presented to the Committee for consideration.

After 30 days have elapsed following this publication, which will afford full opportunity for such criticism and comment upon the revisions as approved by the Committee, it is the intention of the Committee to present the modified rules as finally agreed upon to the Council of the Society for approval as an addition to the Boiler Construction Code. Upon approval by the Council, the revisions will be published in the form of addenda data sheets, distinctly colored pink, and offered for general distribution to those interested, and included in the mailings to subscribers to the Boiler Code interpretation data sheets.

For the convenience of the reader in studying the revisions, all added matter appears in small capitals and all deleted matter in smaller type.

PAR. P–195. REVISED:

P–195. *Heads.* The thickness OF [required in] A BLANK unstayed dished head with the pressure on the concave side, when it is a segment of a sphere, shall be calculated by the following formula:

$$t = \frac{8.33\ [5.5] \times P \times L}{2 \times TS}\ [+\ ^1/_8]$$

where t = thickness of plate, in., P = maximum allowable working pressure, lb. per sq. in., TS = tensile strength, lb. per sq. in., and L = radius to which the head is dished, MEASURED ON THE CONCAVE SIDE OF THE HEAD, in.

Where two radii are used the longer shall be taken as the value of L in the formula.

When a dished head has a manhole opening, the thickness [as found by these Rules] shall be increased by not less than 15 PER CENT OF THE REQUIRED THICKNESS FOR A BLANK HEAD COMPUTED

BY THE ABOVE FORMULA, BUT IN NO CASE LESS THAN $^1/_8$ IN. ADDITIONAL THICKNESS OVER A BLANK HEAD [over that called for by the formula]. Where a dished head has a flanged opening supported by the attached flue, an increase [of $^1/_8$ in.] in thickness OVER THAT FOR A BLANK HEAD is not required. If more than one manhole is inserted IN A HEAD, THE THICKNESS OF WHICH IS CALCULATED BY THIS RULE, the minimum distance between the openings shall be not less than one-fourth of the outside diameter of the head.

THE RADIUS TO WHICH THE HEAD IS DISHED SHALL NOT BE GREATER THAN THE DIAMETER OF THE SHELL TO WHICH THE HEAD IS ATTACHED.

Where the radius L TO WHICH THE HEAD IS DISHED is less than 80 per cent of the diameter of the shell [or drum to which the head is attached] the thickness OF A HEAD WITH A MANHOLE OPENING shall be at least that found [by the formula] by making L equal to 80 per cent of the diameter of the shell [or drum]. THIS THICKNESS SHALL BE THE MINIMUM THICKNESS OF A HEAD WITH A MANHOLE OPENING FOR ANY FORM OF HEAD.

A BLANK HEAD OF A SEMI-ELLIPTICAL FORM IN WHICH THE MINOR AXIS OF THE ELLIPSE IS AT LEAST ONE-HALF THE DIAMETER OF THE SHELL SHALL BE MADE AT LEAST AS THICK AS THE REQUIRED THICKNESS OF A SEAMLESS SHELL OF THE SAME DIAMETER. IF A MANHOLE IS PLACED IN AN ELLIPTICAL HEAD THE THICKNESS SHALL BE THE SAME AS FOR AN ORDINARY DISHED HEAD.

THE DIAMETER OF THE SHELL TO BE USED IN APPLYING THESE RULES SHALL BE THE INNER DIAMETER OF THE SHELL FOR A HEAD FITTED TO THE INSIDE OF THE SHELL, AND THE OUTER DIAMETER OF THE SHELL FOR A HEAD FITTED TO THE OUTSIDE OF THE SHELL.

Unstayed dished heads with the pressure on the convex side shall have a maximum allowable working pressure equal to 60 per cent of that for heads of the same dimensions with the pressure on the concave side.

PAR. P-196. REVISED:

P-196. When dished heads are of a less thickness than called for by Par. P-195, they shall be stayed as flat surfaces, no allowance being made in such staying for the holding power due to the spherical form UNLESS ALL OF THE FOLLOWING CONDITIONS ARE MET:

A THAT THEY BE AT LEAST TWO-THIRDS AS THICK AS CALLED FOR BY THE RULES FOR UNSTAYED DISHED HEADS.

B THAT THEY BE AT LEAST $^7/_{16}$ IN. THICK.

C THAT THROUGH STAYS BE USED ATTACHED TO THE DISHED HEAD BY OUTSIDE AND INSIDE NUTS.

D THAT THE MAXIMUM ALLOWABLE WORKING PRESSURE SHALL NOT EXCEED THAT CALCULATED BY THE RULES FOR AN UNSTAYED DISHED HEAD PLUS THE PRESSURE CORRESPONDING TO THE STRENGTH OF THE STAYS OR BRACES SECURED BY THE FORMULA FOR BRACED OR STAYED SURFACES GIVEN IN PAR. P-199 USING 70 FOR THE VALUE OF C.

If a dished head is formed with a flattened spot or surface [for the attachment of a connection or flange], the diameter of the flat spot shall not exceed THAT ALLOWABLE FOR FLAT HEADS AS GIVEN BY THE FORMULA IN PAR. P-195 (the formula for flat heads to be published later on) [the value of p as given in the formula in Par. P-199 or in Table P-6 for the pressure and thickness of head involved].

PAR. P-197. REVISED:

P-197. The corner-radius of an unstayed dished head measured on the concave side of the head shall not be less than 3 times the [plate] thickness OF THE MATERIAL IN THE HEAD [up to $t - {}^1/_8$ in.]; BUT IN NO CASE LESS THAN 6 PER CENT OF THE DIAMETER OF THE SHELL [for thicker plates the corner-radius shall not be less than 3 per cent of L in Par. P-195, and in no case less than $1^1/_2$ in.].

PAR. P-198. REVISED:

P-198. A FLANGED manhole opening in a dished head shall be flanged to a depth measured from the outside OF THE HEAD AT THE MAJOR AXIS of not less than 3 times the required thickness of the head FOR PLATE UP TO $1^1/_2$ IN. IN THICKNESS. FOR PLATE EXCEEDING $1^1/_2$ IN. IN THICKNESS THE DEPTH SHALL BE THE THICKNESS OF THE PLATE PLUS 3 IN. A MANHOLE OPENING MAY BE REINFORCED BY A RIVETED MANHOLE FRAME OR OTHER ATTACHMENT IN PLACE OF FLANGING.

PAR. P-230*b*. REVISED:

b In a form of CONSTRUCTION [reinforcement] for crown sheets where the top sheet of the firebox is a part of a circle, THAT PART OF THE CROWN SHEET, not exceeding 120 deg. in arc, MAY BE [and is] braced with arch bars extending over the top and down below the top row of staybolts [at the sides] CONNECTING THE FIREBOX SHEET AND WRAPPER SHEET WHERE THESE SHEETS BECOME PARALLEL, these arch bars being riveted to the water side of the crown sheet through thimbles, and the maximum allowable working pressure should be determined by adding to the maximum allowable working pressure for a plain circular furnace of the same thickness, diameter, and length determined by the formula in Pars. P-239 and P-240, the pressure P_1 determined from the following formula, which is a modification of that in Par. P-241*a*:

$$P_1 = 10{,}000{,}000 \frac{b \times d^2}{D_1 \times D}$$

provided that the maximum allowable working pressure must not exceed that determined by the formula for furnaces of the Adamson type, in Par. P-242 when L is made equal to p, and also provided that the diameter of the holes for the staybolts in the crown bars does not exceed $^1/_3 b$, and the cross-sectional area of the crown bars is not less than 4 sq. in. Par. P-199 would govern the spacing of the staybolts, rivets or bolts attaching the sheet to the bars, and Par. P-212*d* the size of the staybolts, rivets or bolts.

where b = net width of crown bar, in.
d = depth of crown bar, in.
D_1 = longitudinal pitch of crown bar, in.
D = 2 times radius of crown sheet.

PAR. P-293. REVISED:

P-293. When shut-offs are used on the connections to a water column, they shall be either outside-screw-and-yoke type gate valves or stop cocks with levers permanently fastened thereto and marked in line with their passage, OR OF SUCH OTHER THROUGH-BLOW CONSTRUCTION AS TO PREVENT STOPPAGE BY DEPOSITS OF SEDIMENT, AND TO INDICATE BY THE POSITION OF THE OPERATING MECHANISM WHETHER IT IS IN OPEN OR CLOSED POSITION; and such valves or cocks shall be locked or sealed open. Where stop cocks are used they shall be of a type with the plug held in place by a guard or gland.

PAR. S-258*c*. REVISED:

c One bend-test specimen shall be taken from the end of the forging corresponding to the top of the ingot. The [axis of the] specimen shall be LOCATED IN A [diametral] plane perpendicular to the axis of the forging WITH ITS MIDDLE POINT ON A RADIUS OF THE FORGING AND THE AXIS OF THE SPECIMEN PERPENDICULAR TO THAT RADIUS.

PAR. M-12. REVISED:

M-12. Every miniature boiler shall be provided with at least one feed pump or other feeding device, except where it is connected to a water main carrying sufficient pressure to feed the boiler OR WHERE [except that when] the steam generator is op-

erated with no extraction of steam (closed system) [no feeding device is required but]. IN THE LATTER CASE, in lieu OF A FEEDING DEVICE [thereof] a suitable connection or opening shall be provided to fill the generator when cold. Such connection shall not be less than $^1/_2$-in. pipe size.

PAR. M-15. REVISED:

M-15. Each miniature boiler shall be equipped with a steam gage having its dial graduated to not less than $1^1/_2$ times the maximum allowable working pressure. The gage shall be connected to the steam space or to the steam connection to the water column by a BRASS OR BRONZE COMPOSITION siphon tube or equivalent device that will keep the gage tube filled with water.

A.S.M.E. Boiler Code Committee Work

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society for approval, after which it is issued to the inquirer and simultaneously published in MECHANICAL ENGINEERING.

Below are given records of the interpretations of the Committee in Cases Nos. 588, 595, 596, 597, 598, as formulated at the meeting on May 11, 1928, all having been approved by the Council. In accordance with established practice, names of inquirers have been omitted.

CASE NO. 588

Inquiry: Will it be permissible in the forming of water legs in vertical tubular and firebox types of boilers, to attach the OG or flanged-in bottom edges of the plates by fusion welding as shown in Fig. 25? Case No. 313 permits of this construction for water legs of detached smokeless fireboxes, but the opinion of the Committee is requested in regard to this construction for water legs forming parts of boilers.

Reply: Par. P-186 of the Code has been revised to provide for joints between the door-hole flanges of furnace and exterior sheets of boilers, provided these sheets are properly stayed or supported around the door-hole opening. It is the opinion of the Committee that where the load due to internal pressure on the plates forming the water leg is carried by staybolting, the construction shown in the figure to the right where both plates are flanged, will meet the requirements of the revised paragraph. The plates may be considered as fully supported if the distance from the weld to the nearest row of staybolts is not more than one-half the pitch allowed by the formula in Par. P-199.

CASE NO. 595 (In the hands of the Committee)

CASE NO. 596

Inquiry: The opinion of the Boiler Code Committee is requested as to the suitable value for the constant C in the formula of Par. P-199 of the Code when applied to miniature boilers constructed of rectangular open-hearth steel pipe or tubing for the shells, the lengthwise edges of which have a continuous support instead of the intermittent support obtained from the use of staybolts. The cross-section of the pipe or tubing will be

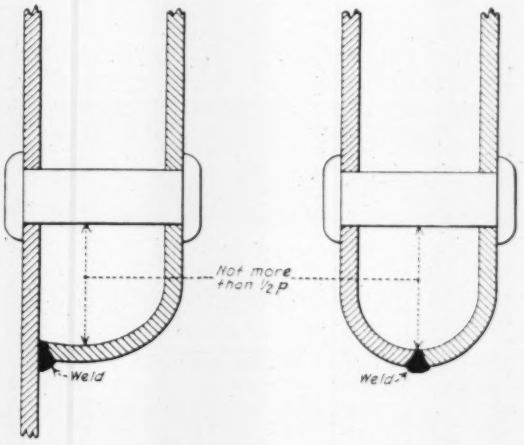


FIG. 25 METHODS OF FORMING WATER-LEG JOINTS BY WELDING

from 6 to 9 in. in its longest dimension and 3 to 5 in. in its shortest dimension, and it is pointed out that for the conditions of use intended it will be desirable to use the thinnest wall permissible down to a minimum of $^5/_{16}$ in.

Reply: It is the opinion of the Committee that for the construction specified, the strength should be calculated by the method given in Par. P-207, and that the plate forming the sides of the box should have a thickness to give the proper transverse strength with a factor of safety of 5 at the maximum allowable working pressure. The length of the plate subjected to transverse stress should be taken as the distance between the inside surfaces of the two sides of the box.

CASE NO. 597

Inquiry: Does malleable iron have any rating of allowable strength in the Code for Unfired Pressure Vessels? In other words, will a cored malleable-iron head in which the steam chamber could be made $^1/_2$ in. deep, meet the requirements of this section of the Code, and how will a correct thickness of the walls thereof be determined?

Reply: It is the opinion of the Committee that any of the materials permitted in Section I of the Code for Power Boilers, although not referred to in Section VII of the Code for Unfired Pressure Vessels, may be used in the construction of unfired pressure vessels, provided the requirements of the Code for Power Boilers corresponding thereto are met. The use of malleable iron for a steam chamber is therefore permissible.

CASE NO. 598

Inquiry: Will it be permissible under the rules of the Power Boiler Section of the Code to use for cleanout openings a special type of plug with gasket attached, which fits into a thimble or nipple threaded into the water leg, instead of the usual form of threaded opening with pipe plug as referred to in Pars. P-266 and P-267? It is pointed out that with this construction there is no danger of crossing threads in inserting the plug and that the tightness is dependent upon gaskets rather than tapering threads.

Reply: There is nothing in the Code to prevent the use of the type of plug described, provided it will meet the requirements of the Code where reference is made therein to such plugs.

Engineering and Industrial Standardization

Plow Bolts

THE tentative American Standard for Plow Bolts was approved in April, 1928, by the American Engineering Standards Committee. This standard was developed by the Sectional Committee on the Standardization of Bolt, Nut, and Rivet Proportions which was organized under the Procedure of the American Engineering Standards Committee in March, 1922, by the Society of Automotive Engineers and The American Society of Mechanical Engineers acting as joint sponsors. Sub-Committee No. 6 of this Sectional Committee was formed to standardize plow bolts.

The National Association of Farm Equipment Manufacturers had previously appointed a committee to standardize plow bolts. This committee was at work on simplifying the list of types of plow bolts then in use. Its first recommendation reduced the total number to seven. Later, at a general conference called by the Division of Simplified Practice, Department of Commerce, the N.A.F.E.M. Committee recommended four types of plow bolts.

Following the Washington Conference in February, 1924, the N.A.F.E.M. appointed one of its members to represent it on Sub-Committee No. 6. The recommendations of the N.A.F.E.M. Committee were then carefully reviewed by Sub-Committee No. 6.

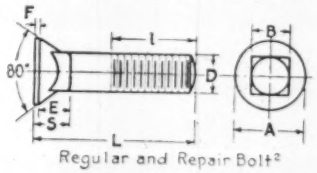
The officers of the Sectional Committee on the Standardization of Bolt, Nut, and Rivet Proportions are: Arthur E. Norton, chairman, and William J. Outcalt, secretary. The members of Sub-Committee No. 6 on Plow Bolts are: E. P. Stahl, chairman and secretary, Ellwood Burdsall, George S. Case, Charles B. Segner, and Oliver B. Zimmerman. The members of the N.A.F.E.M. committee were: A. C. Lindgren, chairman, A. C. Blair, Theo. Brown, L. H. Kanpke, J. Mainland, C. T. Ray, L. W. Squier, and O. B. Zimmerman.

This Sectional Committee has completed standards for Wrench-Head Bolts and Nuts and Wrench Openings; Small Rivets, 7/16-in. nominal diameter and under; Round Unslotted-Head Bolts, Carriage, Step, and Machine Bolts; Tinners, Cooper's, and Belt Rivets; and Plow Bolts; and is now working on those for Slotted-Head Proportions, Machine Screws, Cap Screws, and Wood Screws; Large Rivets; and Track Bolts and Nuts.

Reproduced herewith is a typical page of the standard for plow bolts.

Round Head, Square Neck, Countersunk Plow Bolt

Replaces Old No. 3 N. A. F. E. M. Series



Regular and Repair Bolt[2]

Regular Bolt

D	Threads Per Inch	A		B		Included Angle of Head[1]	S	F	E
Nominal Diameter		Head Diameter		Square Neck[4]			Minimum	Feed Thickness Max.	Minimum
		Minimum	Tolerance +	Maximum	Tolerance −	(deg.)			
5/16	18	0.562 (9/16)	0.015	0.312	0.012	80	0.243	0.025	0.218
3/8	16	0.656 (21/32)	0.015	0.375	0.012	80	0.281	0.031	0.250
7/16	14	0.765 (49/64)	0.015	0.437	0.012	80	0.328	0.036	0.292
1/2	13	0.875 (7/8)	0.015	0.500	0.015	80	0.375	0.042	0.333
9/16	12	0.968 (31/32)	0.031	0.562	0.015	80	0.416	0.045	0.371
5/8	11	1.062 (1 1/16)	0.031	0.625	0.015	80	0.456	0.050	0.406
3/4	10	1.219 (1 7/32)	0.031	0.750	0.015	80	0.491	0.050	0.441

***Repair Bolt*[2]**

D	Threads per Inch	a		b		Included Angle of Head[1]	s	f	e
Nominal Diameter		Head Diameter[3]		Square Neck			Minimum	Feed Thickness Max.	Minimum
		Minimum	Tolerance +	Maximum	Tolerance −	(deg.)			
5/16	18	0.516 (33/64)	0.015	0.312	0.012	80	0.212	0.020	0.192
3/8	16	0.609 (39/64)	0.015	0.375	0.012	80	0.247	0.025	0.222
7/16	14	0.719 (23/32)	0.015	0.437	0.012	80	0.294	0.030	0.264
1/2	13	0.828 (53/64)	0.015	0.500	0.015	80	0.340	0.035	0.305
9/16	12	0.922 (59/64)	0.031	0.562	0.015	80	0.383	0.040	0.343
5/8	11	1.016 (1 1/64)	0.031	0.625	0.015	80	0.418	0.040	0.378
3/4	10	1.172 (1 11/64)	0.031	0.750	0.015	80	0.453	0.040	0.413

All dimensions given in inches.

[1] Note:—The tolerance on the included angle shall be plus 2 deg.

[2] Note:—The reference letters corresponding to the dimensions of the repair bolts are identical with those of the regular bolts but are printed in lower case type.

[3] Note:—To distinguish the repair bolts from regular bolts of the same type, a large "R" shall be stamped on the top of its head or this top surface shall be painted red.

[4] Note:—These dimensions for cold upset wire.

A.E.S.C. Year Book Shows American Industries Making Great Strides in Standardization

IMPORTANT standardization activities in many American industries during the past twelve months are described in the Year Book of the American Engineering Standards Committee, issued June 4. Forty-nine new standards and 40 new projects are listed for numerous branches of industry and engineering, including mechanical, civil, electrical, mining, wood, textile, and safety. One hundred and eleven national standards have been adopted up to the present time by the A.E.S.C.

Continual contact is maintained by the American Engineering Standards Committee with the 19 national standardizing bodies in foreign countries, the Year Book says, with the constant exchange of standards and specifications. The Committee receives daily many requests from abroad for American standards or for information about standards in use here.

A table of preferred numbers, providing a scientific system for determining the sizes of thousands of common commodities, is one of the new standards which is expected to help lessen enormous wastes in industry by eliminating hundreds of needless sizes.

Several national codes for the prevention of dust explosions in terminal grain elevators, flour and feed mills, pulverized-coal systems, and other industries where serious dust-explosion hazards exist—the cause of an annual loss of hundreds of lives and millions of dollars of property—were adopted during the year.

A standard for mathematical symbols recently adopted as the first of a series of standards for scientific and engineering symbols and abbreviations, is expected to help clear up the difficulties arising from variations in symbols used by different authorities.

New electrical standards for dry cells, of ultimate benefit to users of radio and flashlight batteries, standards for industrial control apparatus, and four sets of specifications for insulated wires and cables are listed.

"The completion by a sectional committee of several sections

NEW AMERICAN STANDARDS

The following standards were approved by the A.E.S.C. during the month of May 15–June 15, 1928.

Tinners', Coopers', and Belt Rivets. (Tentative American Standard.)
Sponsored by the A.S.M.E. and the Society of Automotive Engineers. Published by the A.S.M.E.

Ladders and Stairs for Mines. (Tentative American Standard.)

Underground Transportation in Metal Mines. (American Recommended Practice.)
Sponsored by the American Mining Congress. Published by the A.M.C.

Standard Abridged Volume Correction Table for Petroleum Oils. (American Standard.)

Standard Methods of Test for Viscosity of Petroleum Products and Lubricants. (American Standard.)

Standard Method of Test for Melting Point of Paraffin Wax. (American Standard.)

Standard Method of Test for Flash and Fire Points by Means of Open Cup. (American Standard.)

Standard Method of Test for Flash Point by Means of the Pensky-Martens Closed Tester. (American Standard.)

Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosene, and Similar Petroleum Products. (American Standard.)

Standard Method of Test for Distillation of Natural-Gas Gasoline. (American Standard.)

Standard Method of Test for Sulfur in Petroleum Oils Heavier Than Illuminating Oil. (American Standard.)

Standard Method of Test for Thermal Value of Fuel Oil. (American Standard.)

Standard Method of Analysis of Grease. (American Standard.)

Standard Method of Test for Burning Quality of Kerosene Oils. (American Standard.)

Standard Method of Test for Burning Quality of Mineral Seal Oil. (American Standard.)

Standard Method of Test for Burning Quality of Long-Time Burning Oil for Railway Use. (American Standard.)
Sponsored by the American Society for Testing Materials. Published by the A.S.T.M.

Tentative Method of Test for Penetration of Greases and Petrolatum. (Tentative American Standard.)

Tentative Method of Test for Cloud and Pour Points of Petroleum Products. (Tentative American Standard.)

Tentative Method of Test for Neutralization Number of Petroleum Products and Lubricants. (Tentative American Standard.)
Sponsored by the American Society for Testing Materials. Published by the A.S.T.M.

of the work on pipe flanges and fittings marks an important development in standardization activities," the Year Book says.

"The completion of three standards for bolts and rivets marks an advance in the effort to bring about nationwide interchangability of small mechanical parts. The new code for the design of transmission shafting is valuable as a technical basis for the work of machine designers."

Broad revision of the rules of procedure of the American Engineering Standards Committee to keep pace with increasing demands for national standardization activities has been one of the important accomplishments of the past year, according to the Year Book. The procedure has been made more flexible so that it can be applied to any industry and to any type of standard.

Copies of the Year Book may be obtained on request to the American Engineering Standards Committee, 29 West 39th Street, New York.

Mathematical Symbols

APPROVAL of Mathematical Symbols as American Standards has just completed the first step in a program of unification of the scientific and engineering symbols and abbreviations used in engineering and industry, under the auspices of the American Engineering Standards Committee. The confusion resulting from variations in symbols used in different publications, reports, and tables led to the initiation of a project of unification by the Standards Committee early in 1923. The work has been progressing since that time, with 14 national organizations participating.

The approved mathematical symbols include those for arithmetic, and algebra, elementary geometry, analytic geometry, trigonometric and hyperbolic functions, calculus, special functions, and vector analysis. The effort was made to select from symbols already in use those which are most clearly understood and least likely to lead to confusion with other symbols.

Prof. E. V. Huntington, of Harvard University, representing the American Mathematical Society, was chairman of the Mathematical Symbols sub-committee. This sub-committee is part of the Sectional Committee on Scientific and Engineering Symbols and Abbreviations of which Dr. J. Franklin Meyer, of the Bureau of Standards, is chairman. The Sectional Committee includes other sub-committees on symbols for hydraulics, symbols for heat and thermodynamics, symbols for aeronautics, navigation and topographical symbols, electrotechnical symbols (including radio), symbols for photometry and illumination, and symbols for mechanics, structural engineering, and testing materials.

Refrigerator Standardization Progresses

IN THE April issue, on page 328, announcement was made of a forthcoming general conference of manufacturers, dealers, and consumers to consider the establishment of national specifications for domestic refrigerators which would permit their purchase on the basis of quality and performance. This conference was held on March 30 in the Engineering Societies Building in New York at the request of the American Home Economics Institute and the American Institute of Architects, and the 50 representatives of the interests concerned who took part voted unanimously in favor of the proposed standardization work which will be carried on under the procedure of the American Engineering Standards Committee.

The general conference decided that standardization activities, for the present at least, would be devoted chiefly to ice boxes

and other refrigerators which may contain units operated by gas or electricity. Indicating the great economic importance of specifications which will permit the purchase of refrigerators operating at the lowest ultimate cost, the Committee's announcement points out that twelve million domestic refrigerators, representing an annual cost for ice or its equivalent of $26 to $28 for each refrigerator, are now in use.

"The need for specifications to guide the purchaser may be judged from actual tests of three different refrigerators of about the same size conducted by a manufacturer," the announcement adds. "To maintain the same temperature inside the box, one refrigerator melted 22 pounds of ice per day, another melted 28 pounds per day, and a third, 34 pounds. In other words, the third refrigerator required over 50 per cent more ice than the first to maintain a proper temperature. Yet a buyer, unaware of this, might pay more for the poor refrigerator than for the good one. In another test it was found that the use of extra insulation representing a cost of $20 resulted in a saving in ice of about $9 per year, the equivalent of an annual dividend of 45 per cent.

"At the present time, no specifications exist to guide the average purchaser in the selection of refrigerators. He must depend upon appearance, which is misleading, or upon the claims of salesmen who themselves often know nothing about the actual performance of the boxes they sell.

"The general conference was noteworthy for the agreement on the part of refrigerator manufacturers, dealers, and all others that the interest of the final purchaser is of paramount importance. All agreed to cooperate in the work of establishing standards, and on this basis we may look forward to the time, in the very near future, when the housewife will be able to purchase a refrigerator—now one of her most difficult buying problems—with knowledge of how it will perform. Whether she buys a very cheap or a very expensice refrigerator, she will have some knowledge of what she is getting for her money," the announcement concludes.

Correspondence

"Optimism"

TO THE EDITOR:

I was very much interested in your editorial entitled "Optimism" published in the June issue, and was quite astonished at the modesty of the N. Y. U. students, for I cannot help asking myself the question, why spend four years or more at N. Y. U. when you can go to Pratt for two years and earn as much or more.

If you don't believe me, ask Pratt. They have some quite official data which I have been given to understand are based upon information furnished by the graduates themselves, and surely they ought to know.

The report of the Committee on Investigation of Engineering Education does not appear to me to be up to par. If I remember rightly, I have seen something much better than that by the same authority, but perhaps that applied to mechanical instead of electrical men.

Now it appears to me that this sort of thing is pretty poor sport. No one of experience really believes that these statistics indicate the actual conditions, and giving them to young engineers is worse than shooting tame rabbits. You can prove anything by statistics if you use the right kind of ingenuity in picking them, or have a kindly and simple faith in the veracity of those who supply them, but why do we have to guess about the matter? The facts are matters of record, and if the employers will not make them public, the employment experts ought to be able to.

Our engineering societies have an employment department, and surely it is reasonable to suppose that they have on file quite complete data as to the salaries actually being paid to engineers. Why cannot the facts be made public in such a manner that any one of ordinary intelligence can draw reliable conclusions from them?

J. O. G. GIBBONS.[1]

NEWARK, N. J.

The Professional Status of the Engineer

TO THE EDITOR:

Your editorial entitled "What Is the Professional Status of the Engineer?" published on page 408 in the May, 1928, issue of MECHANICAL ENGINEERING, not only presents a very true picture of existing conditions, but also is a fair answer to many of the critics of the Society. Mr. Normile's enthusiastic reception by the Council and President Dow's action on the recommendations presented, show where the Society stands on this problem. However, it is not so much the economic status that worries the young man who is just starting out in the mechanical-engineering profession, but what the future may have in store.

Although Mr. Normile's figures are somewhat startling, I do not believe there is as much need for an investigation into the economic status of the mechanical engineer as there is for an investigation of fields where mechanical-engineering training and talent is not extensively employed. If we are able to show a wider "market" for mechanical engineering, it seems to me that the economic side of the question, namely, the salaries paid, will take care of itself. We need to do more toward "selling mechanical engineering."

The Railroad Division was practically forced into making the investigation that it did because of the general pessimistic feeling on the part of engineering educators and others toward opportunity in the railroad industry. Personally, I do not believe that many men would have thought of the possibilities, especially the opportunity to transfer between the railroad and railway-supply industries, if the fact had not been brought out in the Railroad Division report.

Undoubtedly there are many other allied industries that present the same opportunities which require practically identical experience and training. However, in going into this subject, the members of the committee and others concerned with this work, should not forget that The American Society of Mechanical Engineers is primarily a technical society composed of individuals who are supposed to have the training and intelligence to solve their own individual problems. It is essential that we keep both feet on the ground and not forget our main purpose as a society.

MARION B. RICHARDSON.[2]

New York, N. Y.

A Correction

ON PAGE 446 of the June issue of MECHANICAL ENGINEERING the word "gas" in the third line of the left-hand column should be "cast."

[1] Consulting Engineer. Mem. A.S.M.E.

[2] Associate Editor, *Railway Mechanical Engineer*. Assoc-Mem. A.S.M.E. and Chairman, Sub-Committee on Professional Service, A.S.M.E. Railroad Division.

The Conference Table

THIS Department is intended to afford individual members of the Society an opportunity to exchange experience and information with other members. It is to be understood, however, that questions which should properly be referred to a consulting engineer will not be handled in this department.

Inquiries will be welcomed at Society headquarters, where they will be referred to representatives of the various Professional Divisions of the Society for consideration. Replies are solicited from all members having experience with the questions indicated. Replies should be as brief as possible. Among those who have consented to assist in this work are the following:

ARCHIBALD BLACK,	*J. L. WALSH,*
Aeronautic Division	*National Defense Division*
A. L. KIMBALL, JR.,	*L. H. MORRISON,*
Applied Mechanics Division	*Oil and Gas Power Division*
H. W. BROOKS,	*W. R. ECKERT,*
Fuels Division	*Petroleum Division*
R. L. DAUGHERTY,	*F. M. GIBSON and W. M. KEENAN,*
Hydraulic Division	*Power Division*
WM. W. MACON,	*WINFIELD S. HUSON,*
Iron and Steel Division	*Printing Industries Division*
JAMES A. HALL,	*MARION B. RICHARDSON,*
Machine-Shop Practice Division	*Railroad Division*
CHARLES W. BEESE,	*JAMES W. COX, JR.,*
Management Division	*Textile Division*
G. E. HAGEMANN,	*WM. BRAID WHITE,*
Materials Handling Division	*Wood Industries Division*

Applied Mechanics

Acceleration of Water Flow Through an Orifice[1]

AM-5 If a vessel of considerable area filled with water has a very small orifice at a depth H below the surface of the water and this small orifice is opened in zero time, what time will be required for the velocity of the water issuing from the orifice to equal $\sqrt{2gH}$?

(*a*) The writer has found some of the answers to this question published in earlier issues very interesting.

The time required to establish approximately steady flow must of course depend upon H. If this is much less than 20 ft. the time may be much longer than that suggested by Dr. Epstein, because although the passage of the elastic wave is necessary to establish the accelerating forces on the jet as it builds up, in the case of low pressures the time consumed in the building up of the jet velocity must be long, compared with the time of the elastic wave transmission.

If the tank is deep—30 ft. or more—apparently the time of establishment of the jet is roughly equal to that of the transmission of a pressure wave to the fluid surface and back. The problem is difficult, however, and other factors would probably make the time even shorter than that of the pressure-wave transmission for tanks with very large heads, say, 100 ft. or more.

From an exact mathematical point, Mr. Moody is probably right that the flow builds up exponentially, and that its complete establishment would take an infinite time. Practically, however, the time is very short, as indicated by Dr. Epstein.

[1] This subject has been discussed in a previous issue.

Commenting on this question in the June, 1928, issue, B. G. Lowenstam stated that energy traveled at the rate of 186,318 miles per second. This is true of energy by electrical waves, but the effect of suddenly opening the nozzle is transmitted by an elastic wave in water at a velocity of somewhat less than one mile per second. (A. L. Kimball, Research Engineer, General Electric Co., Schenectady, N. Y.)

Fuels

Unit-Coal-Pulverizer Practice

F-10 What is average good practice with unit coal pulverizers of 2000 to 4000 lb. per hr. capacity as to maintenance, power consumption, and fineness of grind?

These figures will vary with make and size of mill, percentage of full-load capacity being pulverized, moisture content, friability, hardness, and abrasiveness of coal, and the method of taking samples. The following data, however, are representative of the average.

	Maintanance cost per ton, cents	Kw-hr. per ton, total for mill and fan	Fineness through 200 mesh	Moisture, maximum
Pocahontas or New River	2–3	17–18	70–75	10–12
Pittsburgh or equal	3–5	18–22	68–72	10–12
Illinois or equal	5–8	20–25	65–70	12–15
Sub-bituminous	2–5	18–22	70–75	12–18
Lignite	$2\frac{1}{2}$–$3\frac{1}{2}$	16–20	70–75	26–40

(H. W. Brooks, Consulting Engineer, New York, N. Y.)

Fluttering of Oil-Burner Flame

F-11 The flame of a domestic oil burner at certain times flutters violently, setting up a great rattling of the doors and breeching of the furnace. Can any member of the Society suggest possible causes of this action and methods of overcoming it?

In the September, 1927, issue of Mechanical Engineering, page 1026, William C. Groff replied to question F-18, dealing with a slightly different question, and gave information on the fluttering of oil-burner flames which may be of value. However, it is quite possible that other members have had similar experiences and have discovered other remedies than those suggested by Mr. Groff. Their comments are earnestly solicited. [Editor.]

Machine-Shop Practice

Critical Speeds of Cast-Iron Gears

MS-2 What are the critical speeds of cast-iron gears in feet per minute?

(*a*) The following explanation may be of assistance:

1 The final limit is that speed at which the cast-iron ring will burst due to centrifugal force.

2 There are an infinite number of intermediate speed limits dependent primarily on:

a The imposed load—whether uniform or shock

b The character of the metal, heat treatment, etc.

c The accuracy of gear cutting

d The size and form of the gear teeth—pitch, depth, tip relief, pressure angle, fillet

e The gear action—spur, helical, long addendum, size of driver and mate

f The gear mounting—bearings, shafts, housing, gear blanks, balance, and lubrication.

3 Research now being carried on at Massachusetts Institute of Technology has included a study of the dynamics involved, but the Progress Reports of the A.S.M.E. Committee on Strength of Gear Teeth have not yet given a formula suitable for general use. (F. A. Brooks, Chief Engineer, Johnson Gear Co., Berkeley, Calif.)

Materials Handling

PULSATION IN CHAIN CONVEYORS[1]

MH-3 In slow-moving chain conveyors operating at rates as low as or even less than 1 foot per minute there is often present a decided pulsation or jerking of the chain. At times, however, operation is smooth. Can any of the readers suggest a solution of this problem or mention a possible cause of the difficulty?

There appears to be one solution of the problem of pulsations in slow-moving conveyors which has not yet been covered, and this could better be applied in the design.

The usual conveyor drive is through a shaft revolving slowly to carry the chain sprocket of large diameter. The shaft, which may be driven by a comparatively low-powered motor, transmits a very large torque. The huge force tends to twist the shafts designed for strength only. Any twist whatever tends to produce vibrations under the impulses of the pinion teeth. The magnitude of vibration is amplified at the chain pitch line. Under continuous vibration the chain is possibly subject to greater instantaneous movements than would be caused by an equal force applied to the gear as a weight.

The remedy would appear to be in overlooking the shaft as a power transmitting factor for low r.p.m. and in placing the drive gears and pinions immediately adjacent to the chain-driving sprockets.

An investigation of one driver shaft was made by attaching a camera to the spokes of the bevel drive gear and a flashlight or other marker to the spokes of the chain sprocket. Twenty inches of shaft separated the two units. A time exposure while the drive was in operation showed a blurred condition in the direction of rotation. By a suitable scale, the deflection was measured to be about 1/4 in. at the chain. (Thos. P. Colbert, Mechanical Engineer, Burgess Battery Co., Madison, Wis.)

FURNACE GAS AS A CONVEYING MEDIUM

MH-4 It is proposed to use furnace gas as a conveying medium in a pneumatic conveyer, thereby performing both conveying and drying operations simultaneously. Does such an arrangement seem feasible in the face of existing data?

The writer is not familiar with any installations or experiments where furnace gas has been used in a pneumatic conveyor, under combustion, so that the materials conveyed are dried as well as transported. However, the materials conveyed would have to be non-combustible. At the same time they would have to be light. Asbestos, partially dry sand, etc., might meet these requirements, but the number of materials that would not burn, and that at the same time are light enough to be blown along, are few.

It is not difficult to convey fairly large and bulky articles pneumatically. Cash carriers are thus transported in department stores. Burlap sacking has been carried in at least one southern plant. Bulk chemicals are regularly handled in this manner, both from railroad cars and throughout plants by pneumatic conveyors. Powdered coal is likewise carried.

Also, burning furnace gases pass through return tubular boilers and the conveying of such gases is easy, provided the tubes are either surrounded with water, or lined with some refractory material as in chimney flues. Here some solids are carried along and out, as any one near will testify, a lot of cinders and solid particles often being discharged from stacks upon the surrounding community.

The writer imagines that with a suitable material and under a pressure system, burning gases would carry solids and dry them in transit. Discharge could be made to a large receptacle lined with a refractory, outlet to the atmosphere being through a cyclone separator. There might be some danger of explosion unless care were taken to see that combustion occurred within the tubes and unburned gases did not collect within the receptacle, mixed with a dangerous proportion of air.

The question is somewhat veiled, and perhaps more specific information may have to be submitted before a real answer can be obtained. The plan does not seem impossible, and might be easily carried out. (G. E. Hagemann, Managing Editor, *Manufacturing Industries*, New York, N. Y.)

Wood Industries

CRACKS IN CIRCULAR SAWS

WI-1 What are considered the best methods of stopping cracks in circular rip and cross-cut saws.

It is the writer's understanding that a number of saw users have used either of the following two methods effectively:

1 Drill hole at end of crack

2 Regum the saw when practicable and crack is not too deep.

There is a question in the mind of the writer as to the economy of such practice, however, and even when it is resorted to it appears that there should be some standard limit set for the distance from the end of the tooth to the center of the hole drilled, and likewise a limit if the other method is used. This appears to be a question meriting the attention of members of the Wood Industries Division, and is hoped that further discussion will follow. (D. B. Waterfield, Shop Engineer, Chesapeake & Ohio R.R. Co., Richmond, Va.)

WOOD-FLOUR MANUFACTURE

WI-2 Is information available on the manufacture of "wood flour?" Where may one inspect a plant manufacturing this product?

Wood flour is a by-product of sanding operations. At the Victor Talking Machine Company's plant in Camden, N. J., approximately 3000 lb. per day is collected by means of Paxson collectors. This is done not because the flour is desired, but because the dust nuisance must be avoided. The Paxson collector has proved entirely satisfactory for the purpose in this instance; however, any fabric-screen type of reliable manufacture should work equally as well. Speaking for the Victor Company, we are unable to sell this by-product to dynamite manufacturers, as a high percentage of the flour is from mahogany, and this would tend to darken the resulting dynamite, giving it an aged appearance. Properly cleansed, it has a limited use as grease fillers, we are advised. We are disposing of the bulk of our supply to linoleum manufacturers. In no case, however, do we clean the flour, as our present main desire is to dispose of it promptly after collection at a price that will net some slight return on the handling costs. (S. T. William, Works Manager, Victor Talking Machine Company, Camden, N. J.)

[1] This subject has been discussed in a previous issue

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and Attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

The American Society of Mechanical Engineers

29 West 39th Street, New York

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BY-LAW: The Society shall not be responsible for statements or opinions advanced in papers or .... printed in its publications (B2, Par. 3).

The Responsibility of the Applied Mechanics Division

THE steady demand of industry for improved machinery—for bigger, better, stronger, lighter, and more powerful machinery—is opening the door of opportunity for the analytic mechanical engineer.

The first move of the practical designer in complying with industry's demands was a call for better structural materials. To this call metallurgists responded and they are continuing to respond with better mill practices, alloy steels, aluminum alloys, bronzes, and other materials whose properties more nearly fit the needs of industry and the designer, and every such metallurgical advance promptly brings about a demand for still further progress.

In his effort to use new materials economically, the practical designer studies stresses with increasing care and trims factors of safety as knowledge gives him assurance. He is faced with such considerations as complicated elastic phenomena, stress concentration, plastic flow, impact fatigue, and abrasion resistance. As he delves deeper and deeper into the study of stresses he finds that the technical training of a generation ago in the United States failed to include all of the fundamental knowledge now required. This educational deficiency was the natural result of cheap material and ready money, which made refinements in design and theory unnecessary. But economic conditions are now forcing the practical designer to employ every aid of science to assist him in solving problems of design. He can choose between achieving the mastery of these difficult subjects himself by prolonged study, and calling on the analytic mechanical engineer for assistance.

This lays a heavy load of responsibility on the mechanical analyst. He has the goods the practical designer requires. His big job is to sell his wares to the practical man. The policy of the Applied Mechanics Division of insisting that its papers shall be so constructed that their results are readily intelligible and in form for immediate and practical use is an important contribution that this Division is making to the achievements of the Society in technical advances.

G. M. EATON.[1]

Better Riveted Joints

THINGS don't stay put: machines or methods are never safely established, for better or cheaper devices or processes may displace them overnight. Sometimes the ones displaced struggle feebly and succumb. On the other hand, many of the older processes have secured firm positions in fields other than those for which they were originated. When the light and power possibilities of electricity came to be realized some years ago, the obituary of the gas industry was prepared. Mourners are frequently called for the steam locomotive. These two are still lusty because they used the latest developments of progressive science.

Now the talk is about the passing of the riveted joint, which is meeting strong competition from new processes. In the rush of conflict the older method may be pushed too far back and an undesirable action may result. Certainly there are many conditions under which the riveted joint cannot be replaced. There has been no new treatise on riveted joints in the last fifteen years or more, but in that time our materials and our methods of mathematical analysis have taken great strides. The time has come to restudy the riveted joints.

Facts are needed, and the A.S.M.E. is organized, equipped, and willing to assist in getting them.

Solving the Colorado River Problem

A TANGLE of needs, facts, hopes, demands, and guesses—that is the Colorado problem. Five states are involved in a discussion of water supply, flood control, irrigation, power development, and general industrial growth.

As Congress adjourned with the understanding that the Swing-Johnson Bill would be given first consideration at the short session, it may be well to review again the import of this piece of proposed legislation. It authorizes the advance of $125,000,000 from Federal funds to be repaid from the receipts from the sale of water, irrigation developments, and power. Further provision is made for a 550-ft. dam with a storage capacity estimated at 26,000,000 acre-feet; the construction of a power plant in the vicinity of the dam and of an all-American canal 300 miles downstream; and for an equitable distribution of the resources of the Colorado resulting from the development.

A bill known as the Douglas Bill, which has been endorsed by the American Engineering Council, proposes the creation of a commission of engineers to investigate the physical problems connected with the flood control and development of the Colorado River. In endorsing this bill the Council acted on a report of a special committee headed by Francis Lee Stuart and consisting of Allen Hazen, Clemens Herschel, J. Waldo Smith, and Lewis Buckley Stillwell. In the report of this group of outstanding men is the following paragraph:

> Your committee is unanimously agreed that the information set forth in the reports which have been submitted to it is not conclusive as to the engineering feasibility of the plan outlined in the Swing-Johnson Bill, and that before either the Government or private capital would be justified on engineering or economic grounds in com-

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mitting themselves to the expenditure involved, the development of the river for the purpose in view should be further and most thoroughly investigated to determine how the results which it seeks to accomplish can be secured with a reasonable assurance of success.

Dr. Durand's article in the June MECHANICAL ENGINEERING showed the need for solving the problem, which is primarily an engineering one.

Railroad Versus Airplane

DAVID HARUM remarked once that "fleas are good for a dog." Analogically, competition may be good for industries by keeping them from developing too much complacency. The airplane today is the fastest method of transportation known, and in some places its competition is beginning to be felt by the railroads. It is of interest to note how the latter are fighting back. One of the most popular lines of air transportation is the London-Paris. Within the last few weeks the older methods have begun a determined effort to bring passenger traffic "back to earth," as one might say. To do this the following scheme was developed. In the first place, the train from Paris to Calais was speeded up to an average of 62 miles per hour. Next, customs inspection was made on the train, so that no time would be lost on the dock. Finally, the time of each transfer of passenger from train to steamer and vice versa, both at Calais and at Dover, was cut to 10 minutes. With the boat across the Channel and the English train from Dover to London similarly speeded up, it has been found that it takes practically exactly the same amount of time to make the crossing from the center of Paris to the center of London by train and boat that it does to go from Paris to the Le Bourget Field by taxi, fly to Croydon, and ride again by taxi from Croydon to London, with the further advantage that the land and water trip depletes the pocketbook and at times the nervous system considerably less than the trip by air.

Comparison Between Professions

WE ARE constantly being informed that there are too many engineers, that the profession is overcrowded, that engineers are underpaid, and that some sort of combined action to restrict the number of engineers is required. To prove the point, comparison is made with other professions, especially physicians, lawyers, etc.

In making this comparison, unfortunately, sight is often lost of a most important difference in the economic status of the two classes being compared. The physician, for example, is in business for himself; the engineer, in the vast majority of cases, is an employee. We thus compare the so-called average physician, who is in business for himself and runs all the risks of loss in that business, with the engineer, who as an employee only suffers indirectly through loss incurred by his employer's business. If the statistics compared were to be between owners and employee members of the several professions, the results would probably be much different. The salaries paid physicians employed by large organizations and those paid lawyers in real-estate offices searching titles, etc., are much lower than those of their professional confrères who are in business for themselves, i.e., who are "practicing." The compensation of the employed physician and lawyer is probably not greater than that of the employed engineer.

Ownership in whole or in part of the enterprise to which the professional man is devoting his time, energy, and skill is the surest way to receiving a share in that profit which accrues to the enterprise and which is over and above the market value of the skill utilized by the professional man. In order to obtain for himself a share in the ownership of any enterprise, however, the professional man must either have capital with which to start, or something else besides mere skill to trade in exchange for his share. The reason that mere skill will not afford a sufficient trading point is that it is a commodity so easily purchased by persons who do not have the very best discrimination as to selection of values in skill.

There is, however, one characteristic that an engineer or any other professional man can acquire which will afford a very great trading point for ownership, or if he prefers to continue as employee, an extraordinary asset from the view of increased remuneration. This asset may be termed "personality." What is personality? We all have our individual definitions of personality, but perhaps the best one is to call it the sum total of those qualities which distinguish the character of the individual. Is it skill? No, but skill is a part thereof. Is it engineering skill? invention? initiative? persistence? No, it is none of these, but all of these are present within it.

As soon as engineering skill has become a commodity, or, as many engineers think, a drug on the market, one of the surest methods of insuring success to the engineer will be to develop his personality. This will require time and devotion to other matters than the purely scientific side of his work. He will, however, run less chance of becoming merely a technician, which would permit him to become exploited by a corporation employing only his technical skill rather than his entire personality. Let him develop his personality. Let him build up his reputation on that personality to the point where he acquires a public following, even though it be small in number. From that public following he may obtain rights of ownership in an enterprise as a reward of skill. At the worst, his reputation thus built up by the exhibition of his personality in his work and in his contacts will give him an asset which will be easy to trade for higher remuneration even from a corporation.

CROSBY FIELD.[1]

Welding as an Accepted Engineering Method

RECENT events seem to indicate that at least some of the troubles of the welding engineer are over. Notable among these was the awarding of the Lincoln Arc Welding Prizes for 1927 at the Spring Meeting in Pittsburgh. The seventy-five papers submitted to the judges showed unmistakably that great progress has been made. It was shown, for instance, that ocean-going ships are being welded with success, and that the soundness of the practice is such that we may safely predict wide use of the process in the future. A pipe line in Texas over 45 miles in length was welded throughout for operation at 600 lb. pressure. But two of the thousands of joints showed leaks under pressure, and these were inconsequential pinholes, quickly sealed. Quietly for several years this work has been progressing, until now we have many tanks, small boats, shop structures, etc. welded and in daily service. The electrical industry is using welding successfully in the manufacture of large generators. So far as the engineering mind is concerned, welding has arrived. The public, however, must have the practicability or safety of a new development proved over and over again before it will accept it. Therefore laboratories are constantly at work on the problem of making better and more uniform welds—welds which may be accepted with the confidence that all will be safe and that somewhere there will not be one which may fail and wreck the entire structure.

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[1] Vice-President, Brillo Manufacturing Co., Brooklyn, N. Y. Mem. A.S.M.E.

Why Go to College?

IN COMPETITION with the non-college man, the university graduate commences his business career with a tremendous handicap. He is at least four years older, and these four years have been utilized by his competitor in establishing himself in the organization of a business house or industry and in learning countless details of the ways of conducting business which the older graduate absorbs as best he can or acquires by occupying the inferior position of an apprentice. The non-college man has, in these four years, learned valuable habits of industry. Long hours of work, the earning of money, the responsibility of taking his part in an organization where there is no passing mark short of 100, and a chance to "flunk out" every day have given a practical definiteness of purpose to the ambitions of the man whose alma mater is the school of hard knocks. His perceptions of values as they affect him and his business welfare are clearly defined. He has built up for himself a reputation for integrity and ability which is an asset known and recognized by his employees. His early appreciation of the value of money has not come from an academic study of political economy but from earning and spending and saving, now wisely, now foolishly; of being without because of indiscretions, and of making the best of it without writing home for another check. He has accustomed himself to the standards of living of his class. While he may aspire to it, the luxury of club life has not become a necessary condition for his contentment. And he is, perhaps, the employer of the more elaborately educated collegian.

To what purpose, then, is this investment in time and money to become a college man?

Men rate success according to different standards, "Who's Who," "Bradstreet's," and the "Social Register" are variously esteemed as rosters upon which they could have their names inscribed. There is the opportunist par excellence who rides into sudden wealth and notoriety by tricks of fate and unscrupulous conduct, and there is the sensitive scholar whose researches may benefit unborn generations, but whose name is known only to an honorable few and whose philosophy of life is ridiculed by an obtuse world.

On the score of success in life we quote from a "Catechism" by Charles Russ Richards, President of Lehigh University.

In the future, men who lack college education will, without doubt, find it increasingly difficult to achieve success because of the great accumulation of specialized knowledge and the application of such knowledge to the affairs of life and because of competition with college-trained men.

Of the "notables" listed in the 1922–23 volume of "Who's Who in America," 77.4 per cent had college training, 14.1 per cent secondary-school training, and 8.5 per cent common-school training.

In a study of the importance of education Messrs. Hambrecht and Childs assert that the chance of achieving distinction by an individual without education is one in 161,290; by one having eighth-grade education, one in 10,606; and by one having a college education, one in 173.

There are, of course, professions in which a college training is practically essential, such as that of medicine. In engineering conspicuous successes, even in some of its highly technical branches, have been made by men of exceptional ability without the benefit of a collegiate experience. How much more easily these achievements might have been accomplished is of course only a matter of speculation. Some employers have been openly hostile to college graduates, although this type of employer is fast disappearing. In still other businesses it is not so much a technical and bookish knowledge that a man has acquired at college that benefits most directly him and his employer as it is a mental discipline, a breadth of vision, a point of view which distinguishes an interesting personality from an unimaginative drudge. There is also that culture and ease of manner which often makes the young collegian acceptable in situations in which these social graces are essential assets in the conduct of business with high executives. A wide acquaintanceship among men of potential importance and the fact that he is "one of ours," has made the path easy for many men.

"Pike" in the Patent Situation

THERE is an Oriental saying to the effect that the Lord created the pike so that the trout would not sleep too much. The patent business is one particularly suited to provide nourishment for the pike type of person. The inventor, as a rule, is a poor business man, which lays him wide open to all kinds of schemes. It is in this way that quite a business has grown up of fleecing inventors by offering them such plausible schemes as, for example, "no patent, no fee." An impression is given to the inventor that he is perfectly protected, and that if he does not get a patent the attorney will collect no fee. Actually, of course, it is quite easy for a skilful attorney to draw up some kind of claim which the Patent Office will have to allow, no matter how worthless it is. The inventor therefore gets a patent which is not worth the paper it is printed on, spends a substantial amount in filing and issue fees and fees for the patent attorney, and then wonders why no one wants to pay him for the product of his genius.

Another scheme, substantially no more reputable, is practiced by the so-called patent brokers. There are several disguises under which this scheme appears. One of them is to send to the inventor an elaborate-looking document telling him that his patent has been investigated and appears to be of great commercial value. All he has to do to sell the patent apparently is to list it with the broker, pay the latter for preparing an illustrated description of the invention to go to large manufacturers anxiously waiting to have it, and collect the money. Of course the inventor is expected to pay the broker a filing fee and the cost of preparing the illustrations and description, these fees varying anywhere from $20 to $100, and if the inventor does this, as a rule he hears no more from the broker. A member of the Society quite recently applied for a patent on a very minor modification of a part of a machine on which he holds basic patents. In due time the patent was issued and was obviously of no value whatsoever to any one but the owner of the said basic patents. He nevertheless received from one of the patent brokers a glowing letter telling him how many millions of dollars Edison and Westinghouse had made out of their inventions, and how much he could make out of the patent on his little device. Needless to say that, being an engineer thoroughly familiar with the patent situation, he threw the letter into the waste-paper basket. Just why these men are permitted to continue their operations can probably best be explained by the fact that no matter how contemptible they are, they nevertheless are kept within the bounds of formal criminal law.

Quite recently another and in some ways even more disreputable scheme has come to the attention of engineers. Several members of the Society, some of them consulting engineers, received letters from a patent-law firm doing business within the shadow of the Patent Office offering to split fees on whatever business the firm might do with inventors directed to it by these engineers. This is a particularly reprehensible proposal, because to all practical purposes it would make of the engineer a "tout" or "runner" for the patent-law firm. It is to be a secret arrangement and carried out unbeknown to the inventor, and that the fee is split does not make the proposal smell any better. Hitherto the engineering profession has been substantially free from the evil of fee splitting. This is very fortunate, because wherever fee splitting in professional work has gained a footing it has led to the most undesirable results;

nevertheless, when once established it is extremely difficult to displace.

According to published statements by medical authorities, for example, and discussions in the various medical associations, fee splitting between, for example, the general practitioner and diagnostician on the one hand, and the surgeon or specialist on the other is quite common, and at times leads to the former recommending special analysis, X-rays, blood tests, and even operation where the necessity for them is at times far less than evident, but where the rosy prospect of a part of a fee makes the doctor very much inclined to have an operation performed which he might not otherwise have considered it necessary to recommend.

While there is no doubt that engineers as a whole will indignantly reject any such scheme as the secret splitting of fees obtained from inventors by patent lawyers of a certain type, the very fact that at least one such concern had the impudence to broadcast such an offer indicates that there is something wrong with the whole legal end of the solicitation of patents. Mechanical engineers are of course greatly interested in the workings of the patent law, and are anxious to see inventors treated decently and fairly, all the more so as the average independent inventor is not a good business man and hence is in particular need of protection.

The Young Bird Tries His Wings

YOUNG AMERICA has found a new and fascinating playground. Boys who last year sailed boats on the ponds and lakes of our parks are this year tinkering with tiny airplanes that fly—more or less successfully—and which may be expected to fly better as experiments continue. Many of these little craft are carefully designed affairs purchased in the shops, but the greater number are home-made from printed directions or are assembled from kits. Magazines treating scientific subjects in a popular way are conducting regular model airplane-makers' departments. The daily papers, many of them, do likewise, so that it is not difficult for the average youngster of today to learn how a toy airplane should be made and flown. One popular boys' magazine is conducting an airplane-model competition in which more than 100,000 boys are participating. Model-airplane clubs are springing up all over the country. One of the days of the last National Meeting of the Aeronautic Division in Detroit had as a part of its program the Boys' National Model Airplane Contest.

The effect of this sort of play on the boy's attitude toward aviation is not difficult to predict. It is not possible to construct a flying model without gaining some conception of the laws of flight. The wings must be designed according to certain principles. Certain adjustments of the parts must be made to obtain the longest and best-ordered flight, important considerations in the contests just mentioned. These things will be learned and they will become a part of the boy's subconscious development. Ere long he will not be content with mere models—he will yearn for a chance to try his wings at high altitudes. His road will not be so difficult as that of the student who enters a flying school in the raw state. He will have in his subconscious mind certain basic principles which will put him at ease, and which in a moment of danger will not fail him. The development of the reflexes is one of the major problems of the budding aviator. In this respect our flier of models will be well out in the lead of his fellows who have not indulged in this interesting pastime. Aside from these advantages, the model maker will regain much of the early American boy's ability to handle tools; an accomplishment expected of the youth of yesterday, but to a great extent lost in the transition from the farm to the city.

The Rocket Airplane

THE Chinese are supposed to have invented powder long before the Europeans knew anything about it, but they did not apply it to military uses or a different history of the world might have been written. What they used it for was for New Year celebrations—for fireworks. The rocket began in the same way, i.e., as a pyrotechnical device. At some later date its great visibility led to its employment for purposes of signaling, for example, the Coston ship rocket, for which a rather elaborate system of usage has been developed. For a while there was hope that the rocket might be developed into an offensive military weapon, but the invention of the rapid-fire three-inch gun and especially the Stokes mortar put an end to that. It is only lately, due to the work of Professor Goddard, of Clark University, in this country, and more recently, of the German automobile manufacturer Oppel that serious attention has begun to be paid to the possibilities of the rocket as a means of propulsion, and there is talk now of airplanes rocket-propelled and crossing the Atlantic in a few hours, perhaps as few as four or five.

So many apparently impossible and unbelievable things have been brought to a successful conclusion in the last few years that it is not wise to dismiss the rocket's possibilities with a mere wave of the hand. As a matter of fact, an automobile propelled by rockets has actually been operated in Germany recently, and while neither its speed nor its apparent efficiency proved to be superior to what one may today obtain with a gasoline car, it should be borne in mind that this was the first attempt, and that the surprising part lies in the fact that the machine ran at all.

The rocket works on the reaction principle, the reaction involved being that between the rocket chamber and the propellant gases, and not at all between the gases and air, as one might think at first. In fact, Professor Goddard has shown by actual tests that a rocket moves faster in a vacuum than it does under the same conditions in air.

The ordinary pyrotechnical rocket, as well as the Coston ship rocket, is very inefficient, which is due to the fact that, being made mostly of paper, its rocket chamber cannot work with a high pressure; and it is the pressure in the rocket chamber that determines the velocity of efflux of the gases, which in its turn determines the efficiency of the device. Because of this, in an ordinary rocket the velocity of the flow of gases is only of the order of 1000 ft. per sec., and the efficiency scarcely more than 2 per cent. With steel-chamber rockets, velocities of the order of 7000 and 8000 ft. per sec. become possible (these are velocities of the efflux of the gases of combustion, and not of the rocket itself), while the efficiency rises to something like 50 per cent.

The general ballistic properties of the rocket, and especially the question of the reactive power that it develops, are still quite obscure, unless of course Oppel who built the automobile recently tested in Berlin, knows something about them. From such data as are available it would appear, however, that in addition to the ability of the chamber to withstand the gas pressure, several other factors have a vital influence on the efficiency of the rocket. The first of these is the shape of the chamber. In the paper rocket this is cylindrical, which may be one of the main reasons for the inefficiency of that type of rocket. The best results seem to have been obtained with a chamber expanding toward the exit of the gases, somewhat like the expanding part of the De Laval turbine nozzle. Next comes the rate of combustion of the powder, which is in some way related to the shape and size of the nozzle. Thus, cellulose powder gives better results than the conventional saltpeter-sulphur-carbon type, and in large rockets coarse-grained powder seems to be more efficient than finer-grained powder of the same composition.

The rockets used in the Oppel machine are quite probably of the consecutive type, i.e., the type in which several charges of explosive are detonated one after the other in the same steel chamber. The purpose of this is merely to increase the amount of explosive that can be used for the same deadweight of chamber.

Like all engineering achievements, rocket propulsion starts in a crude way, to be refined and developed as time goes on and information accumulates. The chamber may ultimately have to be cooled, and we may yet witness a controversy between the advocates of air and water cooling for transoceanic-type rockets. Powder may be replaced by explosions of gasoline-air mixtures, and the chamber given more complicated shapes and thereby made more efficient.

The spinning top, once a child's toy, has been developed into the gyroscope. There would be nothing surprising, therefore, if the rocket, once an amusement device, should be harnessed to do work in superswift transportation.

Book Reviews and Library Notes

THE Library is a cooperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E. and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references on engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

First-Year College Mathematics

INTRODUCTORY MATHEMATICS. By Joseph E. Rowe. Prentice-Hall, Inc., New York, 1928. Cloth, 6 × 9 in., 285 pp., $2.50.

THIS text covers college algebra, plane trigonometry, including the solution of triangles by means of logarithms, sufficient analytical geometry to equip the student for calculus, and, finally, an introduction to the subject of instantaneous variation, presented in such a way as to stimulate interest in a more advanced course in this subject during the second year. A chapter on college arithmetic outlines the arithmetical principles that underlie the best computing machines.

A practical method due to Prof. E. J. Oglesby, of New York University, is presented by which the quadratic, the cubic, and the biquadratic equation may be solved. The trinometer is also described and it is shown how triangles are solved mechanically, forces and vectors mechanically resolved, and geometrical multiplication and division are made concrete.

Industrial Engineering and Factory Management

REVIEWED BY CHAS. W. LYTLE[1]

INDUSTRIAL ENGINEERING AND FACTORY MANAGEMENT. By A. G. Anderson. Ronald Press, New York, 1928. Cloth, 6 × 9 in., 624 pp., 136 figs., tables, $5.

PROFESSOR ANDERSON has undertaken the most difficult task of writing a 600-page text on applied factory management. The scope is extremely comprehensive for any one man to cover authoritatively. The reviewer feels this same handicap. Nevertheless, the author has done amazingly well, and in most cases has gotten at the kernel of the subject. There is unquestionably a need for such a book, that is, for one less confined to principles than Dean Kimball's "Principles of Industrial Organization" and more given to applied technique.

While "Management's Handbook" covers this same field in an exhaustive and technical manner, its style restricts it more to reference use than to steady reading. Professor Anderson's book can be read by either student or executive with interest as well as profit. It will not compete with the "Handbook," but should pave the way for more constant use of it.

One hesitates to criticize the author for not making his scope still more extensive; the editorial condensation was very great, but in one respect an omission lessens the value and may lessen its use on the engineering side, that is, the almost complete neglect of micromotion study. This highly refined and scientific procedure is merely touched upon in less than a page. Not only does this leave out the best method of job standardization, but it also loses a good deal of the philosophy and principles of waste-motion elimination, which the Gilbreths have matured.

Similarly the chapter on fatigue is conspicuously lacking in Gilbreth contributions, and this is not compensated by giving the recent developments since Mr. Gilbreth's death.

Had the author omitted Chapter 1, and started with Chapter 2 the book would have had a stronger beginning. This is probably, due to the complexity of the material attempted in Chapter 1. Most of those who will be interested in this book will have had special courses in industrial history or will have read books on that subject, so that the limited treatment here will seem sketchy to them. They should not, however, judge the book from this beginning.

While the chapters on organization give some charts which seem fanciful for real use, they include a goodly number of other charts which are taken from what is probably best practice and are refreshing as compared with the older presentations of theoretical charts only.

The material on factory location is perhaps the best available in book form. The many factors involved are well presented, and the chapter is an important contribution. The only criticism possible here is that an actual case of determination is not included. Likewise the material on building planning might be strengthened by something to show how the material is actually used. The only flow chart given is inadequate for typical use. A symbol process chart is more commonly used.

The chapter on material handling is one of the best in the

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book. It gives classifications, tables, and the formula method of determining the economic expenditure for equipment. This formula, by the way, can be used for other equipment than material handling. This is important as the book does not go into the economics of tooling to any extent. The chapters on power, heat, light, and ventilation are splendid, giving about what any one not specialized in those fields would wish to know. The portions on industrial relations are kept to surprisingly small space and yet give the essentials. Safety is the only subject which might be considered slighted.

Many industrialists have long realized the need of more standardized terminology. It is therefore natural that the author should make his own definitions. His attempt to do this should not be criticized, but there is a certain inconsistency in his definitions in the operation-study chapters. Since he has drawn freely from "Management's Handbook," it is unfortunate that he did not adhere more closely to the definitions there given. Up to the time of writing the "Handbook" the field had been controversial, with each faction insistent upon a differentiation between time and motion study. If we confine ourselves to best practice, it is correct to say that every stop-watch study includes some motion study and every so-called motion study includes time study. The real difference is merely a matter of emphasis. The "Handbook" terminology recognizes this and uses the inclusive term "job standardization," whereas the present author goes back to the old distinction and implies that standardization of the job refers to physical factors which are fixed before taking any studies with the stop watch. As a matter of fact, the study of motions, the study of times, and the standardization are all done simultaneously, or a little of each before anything final is established under any of the three headings. For instance, the only sample given of "motion study," page 353, is taken from "Management's Handbook," page 806. This particular motion study was accompanied in the "Handbook" by a corresponding time study, pages 830–31. In this case the times were taken on complete cycles and were not emphasized as much as the motions, but times were studied, and from the reviewer's personal knowledge much timing was done before the motions here given and other physical conditions were finally accepted. Furthermore the material on "time study" is superficial and would not tend to raise the quality of work done in this field. The book ought to indicate the advance of practice since the publication of the "Handbook," but does not. Of course, there are exceptions. The formula for determining times on wood surfacing is excellent.

The chapters on wages will be most helpful to all. The author has been judicious in selecting formulas from the "Handbook" without going into the finer economic details. The worst omission is material on incentives for supervisors, and the reviewer's main regret is that the single graphic chart illustrating incentive plans, page 421, is not on the standard coordinates of production and earning. The examples of earning might also have been carried a few steps further. Only one point of production is given under each plan, and the earning is left for the six hours of an eight-hour day rather than prorated to the full day. The remaining chapters are elemental, but are about all one could expect from the limited space.

There is a wealth of pictures in the book and a goodly number of cases taken from practice. While many of these are confined to the Chicago district, they are mostly valuable. For instance, the description of the Central Manufacturing District is a noteworthy solution to the problem of overhead and distribution for the small plant. The author's use of volume numbers in footnotes instead of dates will be regretted by some as giving no hint to the chronology of articles. There are relatively few mistakes. On page 430, "task times are set higher" should read "tasks are set higher," and on page 418, the second formula for earning under the Halsey plan is wholly wrong for either the 1/4 or 1/2 sharing. The questions at chapter ends should be helpful for classroom work.

On the whole, the book will fill an important place, particularly in schools of business administration. It should be used as an introduction to the many phases of factory management, each one to be followed by more technical and complete treatises. Despite the criticisms here offered, the reviewer feels that the author is to be congratulated and that the book is the best yet written in the broad field.

Methods of Wage Payment

METHODS OF WAGE PAYMENT—A Research Report of the National Metal Trades Association. Chicago, Ill., 1928. Paper, 6 × 9 in., 57 pp.

REVIEWED BY MERRILL R. LOT[1]

THE Committee on Industrial Relations of the National Metal Trades Association has prepared a printed report on Methods of Wage Payment which is particularly significant as it is based primarily upon a field survey of wage procedures in 672 member plants.

The study is divided into two parts, the first analyzing the practices and experiences among the members, while the second offers a comparison of underlying factors which apply to the different incentive plans in vogue.

This research was undertaken to promote a "better understanding of the various incentive plans and methods of wage payment." Its scope was limited to "the relationship between methods of wage payment, the employee, and his pay envelope" and no attempt was made to go into the production, cost-accounting, or other management problems involved.

Pertinent points revealed by the survey are copiously illustrated with carefully prepared graphic charts which give a quick grasp of the contents of the report. This is a particularly valuable and attractive feature. The same procedure of graphic illustration is carried out in the comparative analysis of the various incentive plans in Part II of the report.

The survey reveals incentives for (1) individuals, (2) groups, (3) supervisory forces, and for (4) indirect as well as direct or productive employees.

Some of the significant points revealed through the questionnaires submitted and field surveys conducted among member companies are summarized in the following paragraphs.

Of the 672 plants covered, 45.7 per cent paid employees according to straight time exclusively, while 54.3 per cent based compensation upon some form of incentive, though some of these latter plants used both straight time and incentive plans.

While the preceding description of the distribution of wage methods is very illuminating, there is much significance in finding that 27.5 per cent of all the employees are paid on an incentive basis, while 72.5 per cent are paid for straight time.

Of 489 instances of incentive plans used by 365 shops, 50.5 per cent were on a piece-work basis.

In 245 member shops 70.7 per cent still use their original incentive plans, while 9.8 per cent have changed their procedures. It is of interest to observe that where changes had been made, 33 1/3 per cent were from the piece-work basis to some other incentive plan.

There were 33 cases discovered where incentives were offered to employees on a group basis. Of these instances 29 used the group plan in conjunction with individual incentives.

There were 79 cases of financial incentives for supervisory

[1] Secretary-Treasurer, Metcalf-Lott, Inc., New York, N. Y.

forces, 34.4 per cent of which were based upon a profit-sharing plan yielding extra compensation in accordance with the earnings of the company.

The survey revealed 35 cases where incentives were offered to employees in the indirect-labor group, such as those in the tool rooms and maintenance gangs, and inspectors.

Two hundred and fifty-six of the member firms using incentive plans stressed the importance of careful rate setting when establishing standards of work. Over 74 per cent of these used time studies for establishing these standards, which emphasizes other tested experience, namely, that accurate time studies give the only sure method of establishing equitable rates.

The report warns the members of the Metal Trades Association that only experienced observers should be permitted to carry on time studies, and suggests that where such services are not available within the company's organization, it is wise to seek the assistance of some reputable commercial engineering concern.

In reporting upon the results secured through their various incentive plans, the members state that the benefits derived from their use include increased employee earnings and increased production or lower costs per unit of product.

It is stated that between 20 and 30 per cent difference exists between production and earnings for the same work carried on under an incentive program as compared with the straight time basis. This increase is in favor of the incentive method of payment.

The Committee preparing the report for the Metal Trades Association urges all members of that organization to use an incentive plan, and outlines eight principles which should be followed before deciding upon any one of the many incentive devices available. The Committee rightly includes as the first recommendation that

> The work in question should be studied in detail and definite methods of operation adopted. . . . . the best way to do the job (in payment for which the incentive is being devised) should be carefully and completely determined before anything else is attempted.

The report states that it is difficult to make a direct comparison of the different incentive plans, because of the difference in actual conditions of wage levels and task levels.

In this connection it is to be noted that the report fails to cover a very essential point: the evaluation of the relative financial worth of one job as compared with another. It seems that base rates or average earnings are generally determined on the unscientific procedure of what is generally paid in a given community for a given type of work.

There is great need for approaching these base rates along the lines of a more scientific "job evaluation" and applying the incentives upon such firm foundations as would then result.

It is pertinent to note the following statement of the report:

> . . . . the wage surveys by the National Metal Trades Association show that for given degrees of ability and skill, employees in various shops earn approximately the same amount of money per day period regardless of the type of wage plan used or the accuracy with which the task levels are established.

This latter statement raises such questions as—

1 What means have been employed to measure the "given degrees of skill and ability?"
2 How prevalent is the use of job specifications which have been carefully and completely prepared?

Industry in general has not spoken a "common language" in regard to the various trades and occupations it employs. It has not defined its work requirements, yet job analysis is the very foundation of better understanding and makes for intelligent comparisons of differences between the work conditions in various plants. It is the proper method for developing equitable base rates and incentive plans which may be applied.

An analysis of the progress made by the member companies in the matter of "job evaluation" would have been very helpful. It would have dealt with a fundamental step in good wage procedures. Its omission from the report is all the more to be regretted in view of the general attitude shown by the Committee in its foreword, where it states that ". . . . to a large degree the success and prosperity of American Industry is the result of adequate and just wages."

However, the fact that the report has not dealt with this fundamental does not detract from the value of the work which it has covered.

The National Metal Trades has done a splendid piece of work in explaining the various incentives now in use. Its report is a valuable contribution to the available literature on methods of wage payment.

Books Received in the Library

THE ABRASIVE HANDBOOK. By Fred B. Jacobs. Penton Publishing Co., Cleveland, 1928. Cloth, 6 × 9 in., 547 pp., diagrams, $5.

A reference book on abrasives and grinding practice for the manager, abrasive engineer, superintendent, foreman, grinding-machine operator and student. It points out how many classes of work can be ground advantageously and answers most of the questions confronting the users of abrasive materials or grinding machines. The editor has spent many years gathering data on grinding, and has now published them in this book, the first of its kind.

BESSELSCHE, KUGEL- UND ELLIPTISCHE FUNKTIONEN. (Verzeichnis berechneter funktionentafeln, erster teil. By Institut für angewandte Mathematik an der Universität Berlin.) V.D.I., Verlag, Berlin, 1928. Paper, 8 × 11 in., 30 pp., tables, 3.50 r.m.

In numerous engineering calculations, especially in the fields of electricity, heat, and the strength of materials, numerical tables are needed which cannot be found in the usual handbooks. Tables of various functions, which have been calculated from time to time for various purposes, are scattered in numerous publications and are not easily located. This pamphlet, prepared at the instigation of the Verein Deutscher Ingenieure, gives exact information about all published numerical tables of Bessel, elliptic, and conical functions, telling where they may be found, their compass, exactness, and reliability. It will often save the labor of recalculation.

BRASSFOUNDERS ALLOYS. By John F. Buchanan. Second edition. E. & F. N. Spon, London, 1928. Cloth, 5 × 7 in., 233 pp., illus., 10s. 6d.

The first edition of this book was published at a period when secrecy prevailed in alloying practice. It is now revised to include new methods, new mixtures, and the new standards recently devised by the coordination of effort in the laboratories and in the foundries. The alloys are discussed from the foundry viewpoint with the object of presenting in condensed form the information that is essential to practical foundrymen and engineers.

DIESEL ENGINE DESIGN. By H. F. P. Purday. Third edition. Constable & Co., London, 1928. Cloth, 6 × 9 in., 360 pp., illus., diagrams, tables, 21s.

In this new edition a number of minor alterations have been made to the text of the second edition, and later references to literature have been added. A chapter has been included dealing with some recent developments in double-acting engines and supercharging. A more complete account is given of the twisting effects in crankshafts, and the previous treatment of torsional vibrations has been amplified.

EARLY MATHEMATICAL SCIENCES IN NORTH AND SOUTH AMERICA. By Florian Cajori. Richard G. Bader, Boston, 1928. Cloth, 5 × 8 in., 156 pp., illus., $3.

A history of the development of mathematics, astronomy, surveying, and physics in the western world. Takes up first the Maya symbol for zero, which is many centuries older than our Hindu-Arabic notation. Includes meridian measurements of the earth, the 1761 and 1769 transits of Venus, comets, almanacs, and orreries.

KUHLEN UND SCHMIEREN BEI DER METALLBEARBEITUNG. By K. Gottwein. Second edition. V.D.I. Verlag, Berlin, 1928. Paper, 6 × 9 in., 93 pp., illus., 6 r.m.

A concise handbook on the cooling and lubricating of metal-cutting tools, dies, etc., which has enjoyed great popularity in Germany. It discusses the methods of cooling and lubricating tools, the substances used, their properties and the purposes for which they are suitable. Methods of testing are described and the selection of lubricants for various operations is treated. There are chapters on the recovery of oil and the cleaning of the work, and a section giving the results in practice with various lubricants. The book summarizes wide experience in a practical way.

MEASUREMENT OF AIR FLOW. By E. Ower. Chapman & Hall, London, 1927. Cloth, 6 × 9 in., 199 pp., illus., diagrams, tables, 15s.

This book is intended to serve as a textbook for students and as a work of reference for engineers engaged on matters that involve the measurements of the speeds and pressures of air streams. It deals in a practical manner with the theory and technique of the measurement of air flow and gives references to literature on methods and instruments for laboratory use only. The author has included material on the design of static tubes and the theory of the vane anemometer.

MODERN GASOLINE AUTOMOBILE. By Victor W. Pagé. 1928 edition. Norman W. Henley Publishing Co., New York, 1928. Fabrikoid, 6 × 9 in., 1148 pp., illus., diagrams, $5.

While a certain portion of the previous edition remains unchanged, much additional matter has been included to keep pace with the progress of the industry. Supplementary matter has been added on ignition, starting, and lighting, and new material has been included on buses and rail cars, gasoline-electric drive, front-wheel and four-wheel drive, and steering systems. At the suggestion of teachers a series of questions for review has been placed at the end of each chapter.

THE NEW QUANTUM MECHANICS. By George Birtwistle. University Press, Cambridge; Macmillan Co., New York, 1928. Cloth, 6 × 9 in., 290 pp., diagrams, tables.

This book is concerned with the development of quantum mechanics during the past two years. A detailed account is given of the matrix theory of Heisenberg, Born, and Jordan, the q-number theory of Dirac, and the wave mechanics of Schrödinger. The earlier chapters are devoted to a restatement of the Land's theory of the multiplets in a form which is in consonance with the new mechanics which is to follow; some later chapters are given up to the de Broglie theory of particles and their waves, and to the new statistics of Bose, Einstein, Fermi and Dirac.

The book closes with the resonance theory of the helium spectrum lately given by Heisenberg, and with the new speculations of Bohr on the limitations imposed by the quantum theory upon the possibilities of experimental observation.

PATENT LAW FOR THE INVENTOR AND EXECUTIVE. By H. A. Toulmiss, Jr. Harper & Bros., New York, 1928. Cloth, 5 × 8 in., 288 pp., forms, $4.

The purpose of this book is to present the subject of patent law in a manner that can be assimilated readily by the ordinary business man. Parts of it were published as magazine articles. In addition to the material that is ordinarily found in a book on this subject, there are chapters on the ownership of patents, stimulation of invention by employees, having inventions made to order, the value of patents, their inclusion in the income-tax return, patent pools, and the use of patents to control resale prices.

PRAKTISCHES HANDBUCH DER GESAMTEN SCHWEISSTECHNIK, Vol. 1, Gasschmelzschweiss- und Schneidtechnik. Second edition. By P. Schimpke and Hans A. Horn. Julius Springer, Berlin, 1928. Bound, 7 × 10 in., 222 pp., illus., diagrams, tables, 12 r.m.

This work aims to give a comprehensive, detailed account of gas welding and cutting practice which will meet the needs of the welder and also be of use to engineers and factory managers. The authors have attempted to include everything of value and to reject non-essentials, and to make the book a practical guide to satisfactory work.

The new edition contains more information on acetylene generators, on welding cast iron and non-ferrous metals, on testing welds and on costs.

PRINCIPLES OF FACTORY ORGANIZATION AND MANAGEMENT. By Ralph Currier Davis. Harper & Brothers, New York, 1928. Cloth, 6 × 9 in., 449 pp., illus., charts, $5.

This book is designed to supply students of industrial management, and all executives who desire a complete understanding of factory management, with a clear picture of the fundamental principles and functions. It illustrates the more advanced management practices and trends in modern management theory, and uses many charts and pictures to illustrate the points discussed.

PRINCIPLES OF MECHANICAL REFRIGERATION. By H. J. Macintire. Second edition. McGraw-Hill Book Co., New York, 1928. Cloth, 6 × 8 in., 317 pp., illus., diagrams, tables, $3.

A study course for operating engineers. About 100 pages of text have been added to bring the book as nearly up to date as possible. Numerous typical problems have been solved and new tables and diagrams have been included to assist in the solution of these problems.

The author hopes that the book will be complete enough for instruction in refrigeration where only an introduction to the subject is desired and time does not permit a thorough study of the theory involved.

PRINCIPLES OF THERMODYNAMICS. By George Birtwistle. University Press, Cambridge; Macmillan Co., New York, 1925. Cloth, 6 × 9 in., 163 pp., diagrams, $2.75.

This book contains the substance of lectures given at the University of Cambridge in summer courses, the object of which was to give the fundamental principles of the subject and to illustrate them by applications to branches of science where only a general knowledge of the science was required for their appreciation.

RIEMENSCHLUPF UND REIBUNGSZAHL VON GUMMI- UND LEDERTREIBRIEMEN. By Hans Nowsky. (Versuchsfeld für Maschinenelemente der Technischen Hochschule zu Berlin, heft 8.) Paper, 8 × 11 in., 56 pp., diagrams. Price not quoted.

The elasticity and slip of two rubber belts and one leather belt were measured and the differences between the two kinds of belts treated. The slip was analyzed with the help of three methods of measurement, the creep separated from the slip, and the local slip at any point determined. The determination of the coefficient of friction during running is connected to these measurements.

SCIENTIFIC PURCHASING. By Edward T. Gushee and L. F. Boffey. McGraw-Hill Book Co., New York, 1928. Cloth, 6 × 9 in., 196 pp., charts, forms, $3.

This book does not give in detail the routine of a typical purchasing department, but tries to point out the foundation for successful purchase routine. The actual routine, the author states, should vary with the refinements of a particular concern, and must be given particular study. This book leads up to that study.

It is a textbook of fair dealing between buyer and seller, and is not intended merely for expert purchasing agents but for all who want their trading to be fair.

SIR ISAAC NEWTON, 1727–1927. A Bicentenary Evaluation of His Work. Prepared under the auspices of The History of Science Society. Williams and Wilkins Co., Baltimore, 1928. Cloth, 6 × 9 in., 351 pp., $5.

This book consists of a series of papers prepared under the auspices of the History of Science Society. The papers take up the work of Newton in optics, gravitation, astrophysics, dynamics, fluxions, alchemistry, and chemistry and his work in the mint. Includes an account of the twenty years' delay in announcing the law of gravitation, and his first critical disciple in the American Colonies—John Winthrop.

SNAPSHOTS OF SCIENCE. By Edwin E. Slosson. Century Co., New York, 1928. Cloth, 5 × 7 in., 299 pp., illus., diagrams, $2.

The numerous aspects of the amazing scientific progress of our day are presented for the general reader. The book touches in an interesting manner on recent applications of science to industry and agriculture, contributions of chemistry to medicine, novel inventions, strange discoveries, ancient history of the world and the universe, etc.

JOHN STEVENS, An American Record. By Archibald Douglas Turnbull. The Century Co., New York, 1928. Cloth, 6 × 9 in., 545 pp., illus., diagrams, $5.

Colonel John Stevens (1749–1838) was the leading American engineer of 1880. He built and operated twin-screw propeller steamboats on the Hudson River three years before Fulton's *Clermont*. He built the first ocean-going steamer, the first "steam carriage" ever run on rails in America, and the earliest steam-ferry service in the world.

This biography was written from a collection of private letters, essays, drawings, patents, maps, deeds, and contemporary newspapers, including letters he received and his answers, and documents and pamphlets he had printed or which were sent to him by his friends.

VESTIGES OF PRE-METRIC WEIGHTS AND MEASURES. By Arthur E. Kennelly. Macmillan Company, New York, 1928. Cloth, 5 × 8 in., 189 pp., $2.50.

Since 1800, more than thirty European countries have officially adopted the metric system, and this book is the result of an investigation to find how numerous or important the vestiges of old units might be in commerce and business. It also throws some light on the question of the time it takes for a country adopting the metric system to bring it into general use.

ÜBER DIE FESTIGKEIT DER GEWÖLBTEN BÖDEN UND DER ZYLINDERSCHALE. Edited by E. Höhn. Julius Springer, Berlin, 1927. Paper, 6 × 9 in., 223 pp., diagrams, tables, 10 r.m.

The increasing number of failures of dished heads in cylindrical boilers and pressure vessels has led to this extensive reinvestigation of the question of these heads, under the auspices of the Swiss Society of Steam Boiler Owners. The book consists of two parts: the first, by Mr. Höhn, is a theoretical discussion of the geometrical proportions of compound arches and ellipses, so far as these affect the design of heads; the second, by Dr. Huggenberger, treats the casual relations between the measured values which have been found for heads and cylindrical shells, and the theory of elastic shells.

WATER SUPPLY OF TOWNS AND THE CONSTRUCTION OF WATERWORKS. By W. K. Burton. Fourth edition by J. E. Dumbleton. Two vols. Crosby Lockwood & Son, London, 1928. Cloth, 8 × 10 in., illus., plates, diagrams, 25s., each.

The fourth edition of this work, the first revision in twenty years, has been prepared by J. E. Dumbleton. He has endeavored to preserve the character of the original work while introducing the many changes in practice that have occurred during this interval. Especially, he has altered the information upon water purification and softening, rapid filtration, and pumping machinery.

The book is intended as a reference book for engineers and also for use as a textbook. Volume 1 treats of "Collection and Purification Works;" while volume 2 deals with "Works for Distribution."

Causes of Failure of Wrought-Iron Chain and Cable

THE paper here abstracted is based on part of an investigation carried out since 1924 in the National Physical Laboratory. The full report, by H. J. Gough and A. J. Murphy, authors of the present paper, is in the course of publication.

One of the causes of failure has been found to be overheating, and moreover it has been found that normalization (heating to 1000 deg. cent. and cooling in air) does not restore overheated material.

Another cause of failure is faulty welding, or welding which has deteriorated in service. If the weld is made at too low a temperature or is dirty or incompletely closed during manufacture, a very weak joint is obtained offering low resistance to shock. In this connection the following is important. Under repeated shocks received in service the welded joints tend to separate. If the scarf opens on the outside this can be detected by visual examination. A much more dangerous form of deterioration is that in which the weld separates within the link, and therefore cannot be seen in time.

The tests covered also the effect of repeated static straining, with and without intermediate heat treatment, upon the strength properties of chain and on the mechanical properties and microstructure of wrought iron.

The chief result of the tests is to show that repeated overstraining and low-temperature annealing applied to a wrought-iron chain do not produce any shortness or brittleness, but on the contrary induce a state of great ductility. Therefore annealing following overstraining not only does not reduce the resistance of the chain to shock but increases the shock-resisting properties.

As would be expected, wide variations in grain size exist in any one sample of wrought iron, and this presents some difficulty in estimating the effect of different treatments on grain size. It is evident, nevertheless, that with the conditions of overstraining and with the heat treatments employed, corresponding changes in grain size are not produced, and, more important still, that no combination of overstraining and annealing has produced a coarsened structure. (J. H. Gough, Dr.Sc., and A. J. Murphy, M.Sc., in a paper before the Institution of Mechanical Engineers, Apr. 20, 1928; abstracted through *Iron and Coal Trades Review*, vol. 116, no. 3139, Apr. 27, 1928, pp. 593–595, illustrated, *eA*)

Synopses of A.S.M.E. Transactions Papers

THE papers abstracted on this and following pages appear in the current section of A.S.M.E. Transactions as published in its new form. This section has been sent to all who registered in the Management Division. Other sections are in the course of preparation and will be announced, when completed, in later issues of "Mechanical Engineering."

MANAGEMENT PAPERS

Progress in Management Engineering

THIS report of the A.S.M.E. Management Division discusses progress in the field during 1927 under the following heads: The European industrial situation; economies of industry; business cycles; plants; equipment; labor; standardization and simplification; conservation of material; marketing; clerical operations; safety, traffic devices; fatigue elimination; incentives; research; miscellaneous applications of management principles; management societies; cost finding; education; industrial museums; Management Week; and waste-elimination. [Paper No. MAN-50-1]

Production-Control Methods in the Rubber Industry

By F. B. CALHOUN

Manager, Production-Control Division, Goodyear Tire & Rubber Co., Akron, Ohio

IN THIS paper the author presents a statement of the system employed in the Akron plants of the Goodyear Tire & Rubber Co., discussing respectively its methods in materials control, ordinary materials, production schedules, labor control, dispatching of work, cost data and time keeping, daily reports, organization, and its experimenting with a wage-incentive plan. [Paper No. MAN-50-2]

Coordinating Wage Incentives and Production Control

By D. B. CHARTERS

Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

THE author gives a short account of the various methods that have been tried in the East Pittsburgh Works of the Westinghouse Electric & Manufacturing Company, together with a description of the plan finally adopted and now in use. [Paper No. MAN-50-3]

Production Control in a Wrought-Brass Mill

By W. R. CLARK AND ARTHUR BREWER

Respectively General Works Manager and Works Manager, Mill Products Division, Bridgeport Brass Company, Bridgeport, Conn.

THIS paper describes the scheduling system which has been worked out satisfactorily during the past two or three years in a brass mill. The object of this system is to give better service to customers, to reduce inventories, and to stabilize employment. This paper contains flow sheets of the operations involved and is illustrated by charts and tables showing the variations of flow of material and the mechanism of control. The detailed procedures are outlined. The system accomplishes the following results: It enables careful prediction of the rate of production and means for planning it to meet current business; it enables prompt notification to the customers of the expected date of shipment and insures the fulfilment of this promise; in keeping productive facilities elastic, it permits the controls of semi-finished and finished stocks, the control and reduction of inventories, and an accurate determination of mill hours and number of employees, the whole stabilizing the production rate and ironing out the fluctuation in cost due to variation in the volume of orders. [Paper No. MAN-50-4]

Some Essential Principles for Budgetary Control

By HAROLD VINTON COES

Vice-President and General Manager, Belden Manufacturing Company Chicago, Ill.

THIS paper presents in condensed form many of the essential principles for the application of budgeting to a business and the effective means for control. Some of the means for securing budgetary control are shown in charts and statements of the following: (1) fundamental operating relationships, (2) comparative results of operation for different sales volumes, (3) manufacturing expense budget, (4) indirect labor control, (5) sales and production coordination, (6) sales quota, (7) department quota, (8) comparison of operating ratios. [Paper No. MAN-50-5*a*]

Budgetary Control

By J. P. JORDAN

Consulting Industrial Engineer, Stevenson, Harrison & Jordan, New York, N. Y.

IN THE influence held by a chief executive over the mentalities of his subordinates, whereby he secures from them the greatest possible producing effort, lies the real secret of his success. Many executives hold this influence by sheer personality. Others hold it by a combination of personality and the careful selection and provision of various schemes whereby the subordinates themselves are more or less automatically spurred on in their efforts.

It is a well-recognized fact that we are a nation of aggressive people; that we take business chances as a matter of course. The widespread interest in sports—golf, baseball, football, tennis, boxing, polo, etc.—is evidence of the sporting angles of the average American mind: the apparent evidence of a desire either to indulge in or to become interested in a game.

Budgetary control supplies to every one in any kind of a business institution a species of a game. The setting of quotas of performance and budgets of expense brings out a cool and calculating thought of the future and what it should yield. The daily watching of the current transactions becomes as fully absorbing as the watching of the electric score board of a World's Series game. A par has been set and must be beaten.

The psychological effect of budgetary control is its greatest